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GEOLOGY OF COAL
EXAMINATION OF COAL PROPERTIES
DRIFTS, SLOPES, AND SHAFTS
METHODS OF WORKING

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PREFACE.

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools, is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one, or to rise to a higher level in the one he now pursues. Furthermore, he wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything heretofore attempted, but they must also possess unequaled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the

indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one select the proper formula, method, or process and in teaching him how and when it should be used.

This volume contains papers on the subjects of geology of coal, examination of coal properties, drifts, slopes, and shafts, and methods of working, and will be of service to prospectors, geologists, mining engineers and experts, managers, superintendents of coal companies who are seeking coal lands or who contemplate opening new mines, owners of coal property, shaft sinkers, contractors of mining work, and mine foremen. The papers include all the best information available on the geology of the coal measures, the location of workable coal deposits, location of mine openings, and the most systematic and economical methods of laying out the underground workings and securing the largest possible extraction of the coal underlying a property.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 16, page 26, will be readily found by looking along the inside edges of the headlines until § 16 is found, and then through § 16 until page 26 is found.

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GEOLOGY OF COAL

INTRODUCTION

1. Definition of Geology.—Geology is the science that treats of the development, structure, and present constitution of the earth. Geology aims to trace the progress and development of the earth from the beginning of its existence as a separate planet, through its various stages of growth, to the present. The origin of the planet is properly a subject of astronomy, but as soon as the planet became a solid body rotating in space, its geological history commenced, and as soon as the first land area appeared above the level of the first sea, sedimentation began, and the first geological history was recorded. In this Section will be discussed only such phases of the subject of geology as will aid in a proper understanding of the coal seams. We will endeavor to show what the coal seams are, how and when they were formed, their relation to the other rocks, and other information that will aid in the discovery and intelligent mining of the coal.

The student will be aided greatly in this study if he bears in mind that coal is a rock occurring in layers or beds between other sedimentary rocks, which it resembles in the manner of its occurrence. With the exception of one or two unimportant varieties, coal does not, as do most of the ores, occur in veins filling fissures cutting through other rocks.

2. Crust of the Earth.—The earth is a globe about 25,000 miles in circumference, only the outer portion of which we are able to study by direct observation. Some deep shafts have been sunk to nearly a mile below the

surface; drill holes have penetrated more than 6,000 feet; while some valleys or cañons have been cut to a still greater depth. If the rock strata, or layers that form the crust of the earth, were all lying flat, man would live and travel on the upper surface of the upper layer and could observe the rocks below the surface only so far as the deepest mine was excavated or the deepest valley cut; but where these layers are tilted or turned up edgewise, as shown in Fig. 1,

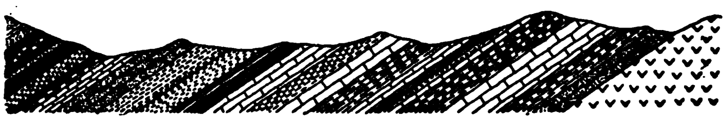


FIG. 1

one can travel over the upturned edges and examine the material in each layer that is exposed at the surface. Thus, if one should start from the Adirondack Mountains, in New York, and travel southwest to the coal regions of Pennsylvania, he would travel over the exposed edges of rocks, as shown in Fig. 1, the aggregate thickness of which is 6 or 7 miles.

It is by studying the exposed edges of the rock layers that the geologist becomes familiar with the different strata composing the crust of the earth and the order in which they occur.

3. Interior of the Earth.—The actual condition of the interior of the earth cannot be studied by observation and is known only by inference. It is found, in deep mines and bore holes, that the temperature increases with the depth. The average rate of increase, as computed from the records of mines and wells in all parts of the world, is 1° F. for each 60 feet of descent. It is not known whether this rate of increase of temperature continues to great depths or not. If it does, at a depth of about 30 miles below the surface the rocks will have a temperature that would be high enough to melt them if they were at the surface, and hence it was formerly supposed that the interior of the earth beyond that depth was in a liquid or molten condition. The rate of

increase in temperature below the surface of the earth is probably not constant, and the fusing point of rocks under the great pressure to which they are subject in the interior of the earth is so high that it is now thought by many that the interior of the earth is solid.

MINERALS AND ROCKS

4. **Composition of Rocks.**—The outer portion of the earth, the part that can be observed, is composed of elements in different combinations. While there are more than seventy of these elements known to the chemist, many of them are so rare that they are not known outside of the chemical laboratory. A comparatively few elements form the bulk of all the rocks and other materials found in the crust of the earth, for probably eight of these elements may be said to form 98 per cent. or more of the rocks as we know them, while nearly 50 per cent. of all the known solid portion of the earth is composed of one of these elements, *oxygen*, which also forms eight-ninths, by weight, of all the water, and nearly one-fourth, by weight, or about one-fifth, by volume, of the atmosphere. Oxygen and silicon in combination as *silica*, SiO_2, constitute nearly 75 per cent. of the composition of all the rocks.

5. **Difference Between a Mineral and a Rock.**—The chemical union or combination of the elements in different ways forms the **minerals**, which in turn make up the different **rocks**. As a mineral may consist of one or several elements, so a rock may consist of one or several minerals. Thus, the mineral graphite contains only the element carbon, while feldspar consists of the elements oxygen, silicon, aluminum, and one of the alkalies, potassium or sodium. The rock limestone consists of a single mineral, calcite, while granite contains three or more minerals. A mineral has a definite chemical composition and generally a specific crystalline form, while a rock does not necessarily have either.

PROPERTIES OF MINERALS

6. Minerals are identified and distinguished from one another by different physical properties, such as *hardness color*, *streak*, *luster*, *crystalline form*, *cleavage*, *fracture*, *specific gravity*, and by the difference in their chemical composition It is seldom that a mineral can be identified by any single one of these properties, but it is necessary to compare several or sometimes all of the properties. Thus, the mineral magnetite has a black color, as have many other minerals, but the other black minerals will have a different crystalline form, cleavage, luster, or hardness from the magnetite, and it is by considering all of these properties that magnetite is separated from other black minerals. There are many degrees of **hardness** among minerals; so, for convenience, certain well-known minerals have been selected, arranged, and numbered in the order of their hardness, thus forming a scale of comparison, as follows: 1, talc; 2, gypsum; 3, calcite; 4, fluorite; 5, apatite; 6, orthoclase (feldspar); 7, quartz; 8, topaz; 9, corundum; 10, diamond. Any mineral in this scale will scratch the one preceding it and will be scratched by the one following it. Thus, No. 3, calcite, will scratch No. 2, gypsum, but will be scratched, in turn, by No. 4, fluorite.

Minerals vary widely in **color**, and sometimes the same mineral occurs in different colors, yet color is an important aid in identifying the mineral.

The **luster** may be metallic, glassy, pearly, or silky. The **streak** refers to the color of the mineral in a powdered form, which is often different from the color of the lump. The streak may be ascertained by scratching the mineral with the point of a knife, file, or otherwise. The **crystalline form** of the mineral is an important aid in its determination, as most minerals have certain forms in which they always occur.

The **cleavage** refers to the surface or surfaces along which the mineral splits or cleaves more or less readily. Thus, calcite cleaves readily in three directions, giving three

bright faces inclined to one another, while feldspar cleaves in two directions, at right angles, or nearly so, to each other; mica cleaves in but one direction, and quartz does not cleave at all, but breaks with a rough surface known as the fracture.

ROCK-FORMING MINERALS

7. Of the many hundreds of different minerals, the following are the principal ones that form the bulk of the common rocks, the others occurring in small quantities in certain localities.

QUARTZ

8. Oxide of silicon, SiO_2, or **quartz,** is the most abundant of all minerals. It is quite hard, 7 in the scale of hardness, and readily scratches glass. It does not dissolve in water or any of the ordinary acids. It crystallizes in six-sided prisms with irregular six-sided pyramids, as shown in Fig. 2. It has no cleavage, but breaks with a rough surface. It is commonly white or gray in color, sometimes transparent, sometimes black, red, violet, yellow, or brown. It forms the glassy part of the granite rocks, and the greater part of the sands and pebbles of the sea and lake shores, and the sandstones and conglomerates. It forms the flint nodules of the chalk and limestone beds.

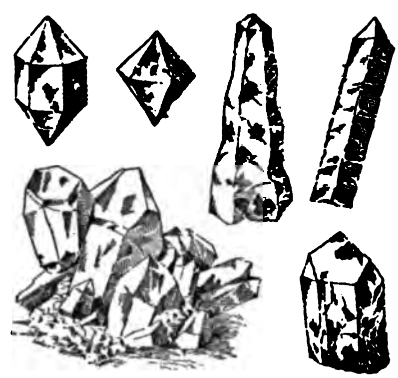


FIG. 2

SILICATES

9. The **silicates** are formed by the union of silica with one or more of the other elements, and, as silica combines in varying proportions with almost all the elements, the list

of silicates is very large. Next to quartz, they are the most important rock-forming minerals.

10. Feldspars.—The feldspars, which are silicates of alumina and potash, soda, or lime, are 6 in the scale of hardness, being hard enough to scratch common glass, but not so hard as quartz. They have cleavage in two directions, and are usually white, gray, or flesh red in color. They crystallize differently from quartz. Some of the common forms of the crystals are shown in Fig. 3. The one that contains potash is called *orthoclase*, and is the one that occurs in the granite rocks; those containing soda and lime are known as *plagioclase*, and occur in most rocks.

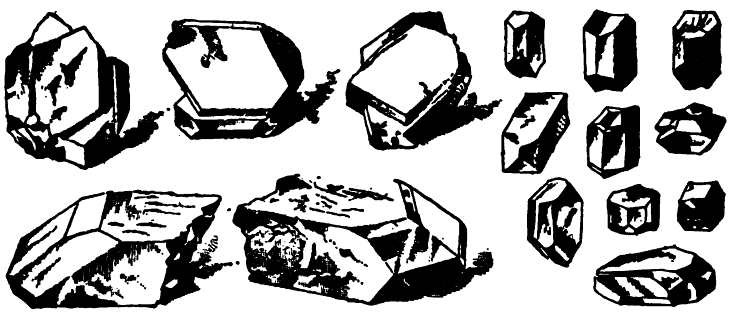


FIG. 3

11. Kaolin, the silicate of alumina containing water, is produced by the decay or disintegration of the feldspar, the mineral being changed from a hard rock to a soft, earthy powder. When pure, it forms china clay; when mixed with impurities, it is thought to be the base of all the common clays, shales, and slates; and when mixed with sand or silica, it forms the bulk of all the soils.

12. Micas.—The micas are silicates of alumina with potash, iron, magnesia, and water. They cleave readily, in one direction, into very thin leaves. They have a brilliant luster, and are between 2 and 3 in the scale of hardness. *Muscovite* has a light, nearly white, color, and *biotite* is usually black or dark green. They are very common

minerals in the granites and allied rocks, and occur as small, bright, shining scales in many sandstones.

13. **Hornblende** and **pyroxene** are silicates of magnesia, calcium, iron, and aluminum. They occur in different colors, but are most commonly black or dark green. They are very abundant in the igneous rocks. Hornblende often occurs in long slender crystals; asbestos is a variety of it.

14. **Talc, serpentine,** and **chlorite** are hydrous silicates of magnesia. Talc is very soft (1 in the scale) and has a soft greasy feel; in the massive form it is called **soapstone.** It is white, grayish, or greenish in color. Serpentine is usually dark, sometimes yellowish green; while chlorite varies from a light to a dark green.

Fig. 4

CARBONATES

15. **Carbonates** are formed by the union of carbon dioxide, CO_2, with an oxide of one of the metals. **Calcite** is the carbonate of lime that forms the limestones and marbles. It crystallizes in different forms, as shown in Fig. 4, and cleaves readily in three directions. It occurs in different colors, white, gray, black, and red being quite common. It is a soft mineral, 3 in the scale of

hardness, and can be scratched easily with a knife. It dissolves readily with effervescence or bubbling in a dilute acid, and when heated to a high temperature in the lime kiln or elsewhere it changes to quicklime without melting.

Dolomite is a double carbonate of lime and magnesia, and differs from calcite in having part of the lime replaced by magnesia. Many of the limestones and marbles consist of dolomite.

Siderite is the carbonate of iron that forms the black band ore and the clay ironstone in the clay beds along with the coal seams.

Gypsum is a sulphate of lime combined with water, and is much softer than calcite (2 in the scale of hardness). It occurs in different forms: in clear crystals, it is called *selenite;* and in a white massive form it is called *alabaster.* When heated to drive off part of the water, and ground to powder, it forms plaster of Paris. It occurs as crystalline masses and extensive beds in the shales, and is often associated with coal and with rock salt.

IRON MINERALS

16. Pyrite, a compound of iron and sulphur, is found in scattered crystals and masses in nearly all rocks. It occurs, to a greater or less extent, in all coal seams, and is usually known to the miner as **sulphur**. It is yellow, often

FIG. 5

golden yellow, in color, and occurs as thin layers between the layers of coal or in the roof strata; or as cubical crystals scattered through the coal or shale. The form known as *sulphur balls*, shown in Fig. 5, is a somewhat rounded mass of pyrite. Sulphur balls occur with great frequency in

certain coal seams, and also in the floor and roof of the seams. Pyrite is frequently mistaken for gold, and is sometimes called *fool's gold*. It can easily be distinguished by putting it in a fire, when it will burn with a blue flame and white smoke and give off the odor of sulphur. It is also harder than gold, and, like flint, gives off sparks when struck with a pick. Gold is malleable and can be hammered into thin plates, but pyrite is brittle and flies to pieces.

17. **Hematite** is the oxide of iron called *red hematite* when it is free from water, and *brown hematite*, or *limonite*, when it contains water. Both of these oxides occur in different colors and forms, but they can readily be distinguished by powdering a little of the mineral; the red hematite always gives a red powder, and the limonite a brown or yellow powder. These two minerals are the most important ores of iron in this country, as probably nine-tenths of the iron is made from them. Diffused through the rocks, they form the yellow, red, and brown coloring matter in all soils and in many of the rocks. The red shale underlying the coal strata in Pennsylvania and the adjoining states obtains its color from the red oxide of iron it contains.

18. **Magnetite** is the black oxide of iron that differs from the other oxides in color and in being magnetic. It generally crystallizes in the form of octohedrons, or eight-sided figures. It is not commonly found among the sedimentary rocks, but occurs generally in the older rocks. It is a valuable ore of iron.

CLASSES OF ROCKS

19. Rocks are commonly divided into three general classes: *igneous rocks*, *sedimentary rocks*, and *metamorphic rocks*.

20. **Igneous Rocks.**—Igneous rocks are those that have cooled from a fused or molten condition. There are many kinds, depending on the chemical composition of the rock and the conditions under which the material cooled. Where the solidification took place at great depth under great pressure, the process was a slow one, and resulted in

coarsely crystalline rocks, such as granite and syenite, which are the most common rocks of this class. They are the deep-seated rocks, occurring in extensive masses, and sometimes called Plutonic rocks. Some of these are the oldest rock beds we know, and hence, geologically, underlie all the others, though they may have been upheaved and disturbed by some later movement of the earth's crust.

Granite, one of the best known of the coarsely crystalline igneous rocks, is commonly light to dark gray or reddish in color, and is composed of quartz, orthoclase feldspar, and, generally, mica or hornblende, or both. It forms the axis of many mountain ranges, and is seen where the newer rocks have been worn away by water or ice.

Syenite resembles granite in color and general appearance, but differs from it somewhat in composition, consisting

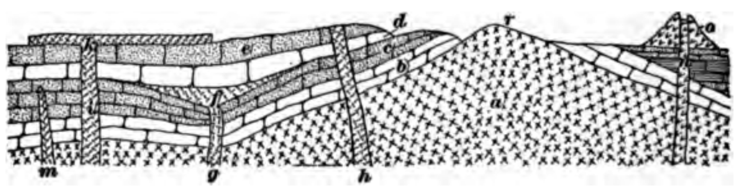


FIG. 6

essentially of orthoclase feldspar, and hornblende. Mica and hornblende occur in both granite and syenite, but the mica is more common in granite, and hornblende in syenite. Granite has considerable quartz, while syenite has little or none.

The other Plutonic rocks differ from granite and syenite in composition. There are also many varieties of fine-grained and glassy igneous rocks that were formed by the cooling of molten lava at or near the surface.

Fig. 6 illustrates a number of the common forms in which igneous rocks occur. They may underlie other rocks, forming masses as at *a*, or form a ridge or core of mountain ranges, as at *r*. They frequently appear as vertical sheets, filling fissures or cracks in the rocks, forming dikes, as at *h*, *g*, *i*, *m* or *n*. They sometimes occur as beds of material forced in between the strata, as at *f*, or as overflows on the surface, as at *k*, or the overflow may form a volcanic cone, as

at *o*. Frequently, the dikes or fissures, which are filled with eruptive material, do not break clear through to the surface, as shown at *m*; when such is the case, the existence of the dike will only be known after the overlying strata are removed by erosion, or it is possible that such dikes might be encountered during mining operations.

21. **Sedimentary Rocks.**—The igneous rocks, when exposed to the atmosphere, disintegrate—that is to say, break up and crumble. The rain and the streams carry away this fine material and deposit it as beds of gravel, sand, or mud, which in time are changed to hard rocks. Such rocks are called **sedimentary, or stratified, rocks,** because they are formed of material deposited as sediment from the water, and hence are stratified or arranged in regular layers. Nearly all the rocks associated with coal beds belong to this class. The principal sedimentary rocks are:

Sandstone, which consists of grains of cemented sand, together with some substance, as iron oxide, lime carbonate, clay, or silica.

Conglomerate, which consists of gravel or pebbles cemented together, as the grains of sand in the sandstone.

Shale, which consists of hardened mud, and is composed of clay often mixed with more or less fine sand. This is the rock that most commonly overlies coal; when associated with coal, it is commonly of a black color, due to the carbonaceous matter it contains. Sometimes it is red, as the Mauch Chunk red shale, which underlies the conglomerate. The red color is due to the red oxide of iron it contains.

Clay, which is derived mainly from kaolin, is a mixture of alumina, silica, iron, lime, magnesia, potash, soda, and varying quantities of impurities. *Mud* is an impure clay and does not have the laminated structure of the shale, neither is it so hard. Fireclay, which often underlies coal seams, consists mainly of silica and alumina, containing little iron, lime, magnesia, potash, or soda.

Limestone, which is generally formed of the shells and bones of animals that formerly lived in the water. These

hard parts are sometimes ground into fragments or even into fine mud by the action of the waves and boulders. The deposition of lime carbonate among the shelly fragments, or in the mud, cements the particles and forms the hard limestone.

Gypsum, which is more local in its occurrence than any of the other sedimentary rocks, and occurs in beds of shale and clay generally associated with coal or rock salt. It consists of sulphate of lime and water, and may have been formed by precipitation from concentrated sea-water or by the chemical action of iron sulphate on lime carbonate.

22. Metamorphic Rocks.—There is another class of rocks, intermediate between the igneous and the sedimentary, known as **metamorphic rocks**. The term *metamorphism* signifies a change of form or structure, and metamorphic rocks have been formed from sedimentary or igneous rocks by a more or less marked change in the form or texture of those rocks. Thus, marble is a metamorphosed limestone, the limestone having been rendered more crystalline and generally harder. Sandstone, when subject to metamorphism, is changed to quartzite, a much harder rock. Clay or shale may be changed, by metamorphism, to hard roofing slate. Bituminous coal is changed to anthracite, and might be further metamorphosed to graphite. Other metamorphic rocks are serpentine, gneiss, and various kinds of schist.

Metamorphism may be brought about by the action of one or more of several agencies, such as heat, pressure, water, and alkalies. The action of heat in metamorphosing rocks is shown where molten rock in the form of dikes or volcanic rocks cuts through sedimentary layers. Where a dike or fissure filled with igneous rock cuts through a bed of bituminous coal, the coal for some distance on each side of the fault may be changed to anthracite, or in some cases to natural coke. The combined action of heat and pressure is shown by the metamorphosed condition of coal seams where the rocks are much folded and disturbed, the metamorphism

increasing with the amount of folding, which is probably due, in a large measure, to the heat generated in the crushing and folding. Hence, we find, as we should expect, greater metamorphism in the folded rocks of mountainous areas than in the flat-lying rocks of the plains. There are few metamorphic rocks in the Mississippi Valley, but a great many in the Appalachian and Rocky Mountains. Anthracite occurs in the midst of the sharply folded strata of Eastern Pennsylvania, while in Western Pennsylvania and in the Ohio and Mississippi Valleys, where the strata have not been folded, the coal is bituminous.

GEOLOGICAL AGENCIES

23. A **geological agency** is any natural force that produces change either in the *kind* or *location* of rock materials. These agencies may be classed as *atmospheric*, *organic*, and *aqueous*.

ATMOSPHERIC AGENCIES

24. The **atmospheric agencies** are: (1) Changes in temperature, which produce alternate freezing and thawing of the water absorbed and held to a greater or less extent in the pores of all rocks. The expanding of the water in freezing acts as innumerable little wedges to split the rock into small fragments. The same agency acts more powerfully when the water, in considerable quantity, occupies a crack, crevice, or joint in the rock. (2) The oxygen, carbonic acid, nitric acid, and other chemical agents in the atmosphere produce chemical changes in the minerals composing the rocks and then assist their disintegration. (3) The force of the wind, which in many localities lifts and transports large quantities of sand, and by its constant action erodes and cuts away rocks and cliffs against which it strikes. The hardest granites may be worn down in this way.

ORGANIC AGENCIES

25. Plants, and to a certain extent animals, are active agents in the disintegration of the rocks. The growth of roots in the crevices and fissures splits and wedges apart large masses of rock. The boring propensities of certain animals destroy many of the softer rocks, besides making openings for the water to penetrate, thereby exposing them to the chemical action of both air and water. The acids coming from vegetation are active agents in dissolving and breaking up the mineral compounds.

AQUEOUS AGENCIES

26. **Aqueous agencies** are those in which water plays a part, the water acting chemically as a solvent, or mechanically to erode rocks and transport the fine material to other localities. The fall of rain, the flow of rivers and streams, the beating of waves on the shore, the chemical action of mineral waters, are all illustrations of more or less active aqueous agencies.

The rain that falls on the surface of the earth partly evaporates and passes off as vapor; part of it runs off as surface water to the streams and thence to the sea, and part of it sinks into the earth, where it is known as underground water, or ground water.

27. **Action of Surface Waters.**—That portion of the rain that flows off as surface water through the gullies and depressions to the streams and thence to the sea is an important agent in modifying and sculpturing the surface of the earth. Acting in conjunction with the disintegrating effect of the atmospheric agencies, it is the chief factor in cutting out the valleys and wearing down the hills.

28. **Action of Underground Waters.**—In reference to mining, it is important to study the strata with respect to their character as being pervious to water or otherwise. Strata in which water accumulates are called **water-bearing**

strata. The underground water sinks into the soil and penetrates the underlying rocks to varying depths, according to the character of the rocks and the inclination of the strata. The rate and direction of the movement of water underground depend likewise on the same factors.

Underground water may be considered as forming two zones—the lower, a permanent zone of saturation, and an upper, temporary zone nearer the surface. Everywhere at a variable distance beneath the surface, the rocks are saturated with water. The depth of this zone of saturation below the surface depends on the climate, the character of the rocks, and the nature of the surface. It lies nearer the surface in a wet climate than in a dry one, and nearer the surface in the valleys than in the hills. As might be expected, there will be greater quantities of water encountered, and hence greater expense in mining, below this zone than above it. Above the zone of permanent saturation, there is a temporary zone where the water rises nearer the surface in wet seasons and sinks in dry seasons. Hence, a mine above the permanent zone of saturation may be troubled with water during the winter and spring and be quite dry in summer and autumn. Some of the strata are quite porous, and through these the water percolates freely. Other strata are more or less pervious to water, in some cases the strata absorbing and holding the water in the pores of the rock in large quantities; while still other strata, particularly the clays, are impervious and prevent the water from passing through them. Coarse-grained sandstones are quite pervious to water. Finer-grained sandstones, as also some shales, often hold large quantities of water by the capillary attraction in the pores of the rock; hence, a coal seam that is overlain by a heavy bed of shale free from faults is likely to have a dry roof, even though the shale should be saturated with water, because it does not readily permit the movement of water through it, but holds it by capillary attraction. If the shale is thin or wanting in places, and is overlain with sandstone or conglomerate, the mine is likely to be wet from water pouring in from the sandstone. Mines are often

suddenly and seriously flooded by a thin place in the shale roof breaking through and permitting the inflow of water from an overlying water-bearing stratum. Where the beds are inclined at a high pitch, there is often trouble from water coming in from the bottom. The best natural protection in such a case is a heavy bed of fireclay. If the underclay is thin or irregular, and underlain by a bed of coarse sandstone, it may become a source of danger, and an opening made through the clay may result in flooding the mine.

29. Another practical effect of underground water in mining is the enormous pressure exerted by the water on an impervious roof stratum; or in inclined seams this pressure may be exerted on the clay floor of the mine workings. In such cases, it frequently becomes very important to avoid breaking the roof stratum, until that portion of the mine may be abandoned. The pressure acting on the floor may cause the bottom to heave in the workings of a mine.

Fig. 7 illustrates a simple method in which a spring may be formed. The water falling on top of the hill *a* settles through the porous formation until it reaches the impervious bed *b*, which may be composed of clay, shale, or rock. The water flows along the top of this bed and appears as a spring at *c*, where the impervious strata outcrop. Since most coal seams are underlain by a bed of fireclay that is impervious to water, it frequently occurs, where there are water-bearing strata above the seam, that the outcrop of the coal can be traced by the numerous springs along the hillside. The action of underground water forms many limestone caves and sink holes. The water, carrying acids in solution, dissolves the limestone in its course, thus forming open passages or caverns. As the cave enlarges in the course of time, portions of the roof become so thin as to drop in from their own weight and that of the overlying soil (see Fig. 8).

Fig. 7

30. Glaciers.—Streams of ice, known as **glaciers**, are important agents in modifying the surface features of the regions where they occur. The snow that falls high on the mountains is gradually compacted into ice by the pressure of the mass, and by alternate melting and freezing, and the ice creeps or flows down the valleys like a great sluggish river. Large quantities of stones, earth, and other subtances fall on the ice from the cliffs and are carried along with the same ease as chips on a stream of water. The boulders, gravel, and sand that are frozen into the bottom of the ice stream act as so many engraving tools to cut and wear away the rocks over which they move. While the general process is a leveling one that tends to smooth and make

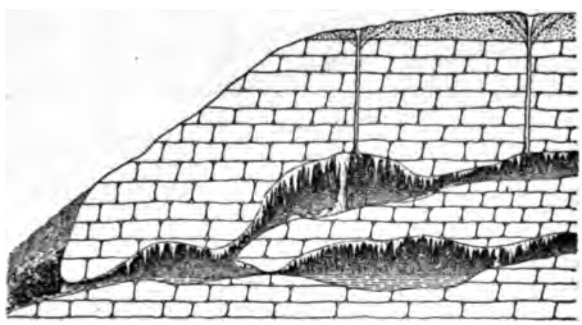


FIG. 8

more even the surface over which the glacier flows, it is at times irregular in its action, riding over some inequalities and planing off others, filling up some depressions and scooping out others.

The rock material carried by a glacier forms the masses of gravel, sand, and clay called **moraines**. The accumulation at the lower limit of the glacier is known as the *terminal moraine*. The material carried underneath the ice is the *ground moraine*, and in the glacial deposits it is known as *till*, or *boulder clay*, consisting generally of a tough clay interspersed with numerous boulders of various sizes. All the material deposited by the glacier, irrespective of the form or character of the deposit, is known as **glacial drift**.

31. At one time, a great ice sheet covered all the northern portion of the United States, and extended over a large part of the coal fields of Pennsylvania and the northern part of the Mississippi Valley. This glacier, as it passed over the coal fields, scraped off the outcropping edges of the coal seams and other strata. In other places, it plowed deep furrows in the basin, eroding the seam completely. These furrows often became filled at some later period with drift

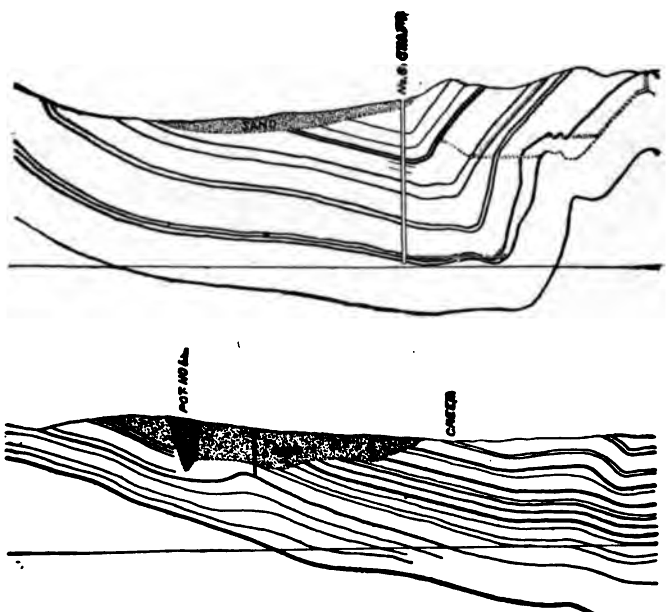


FIG. 9

or sediment deposited from overflowing waters. Another feature of glacial action is the complete damming of a narrow gorge or waterway and the subsequent filling of the space behind the dam with sediment. This is done rapidly, on account of the large amount of mud and other sediment resulting from the melting glacier. This gives rise to what in geology are called *buried valleys*. They are a source of great danger and a serious menace to life and property where they intercept coal seams. There are many of these

buried valleys through Central and Southern New York and Northern Pennsylvania, and in the coal fields of Iowa, parts of Missouri, Illinois, Indiana, and Michigan. The buried valley of Wyoming, between Pittston and Nanticoke, Pa., in the Northern Anthracite field, is one of these old glacial valleys that has already caused the loss of many lives, the destruction of several mines, and still remains a constant menace to all the mines in its proximity. Fig. 9 shows the condition in this buried valley.

ACTION OF GEOLOGICAL AGENCIES

32. **Weathering.**—The action of the several agencies producing disintegration of the rocks is known as **weathering**. These agencies are not everywhere equally active, but they are all more active in moist than in dry climates; thus, the stone monument called Cleopatra's needle, which stood for many centuries without injury in the dry warm climate of Egypt, began to crumble in a few years in the cool moist climate of New York.

33. **Weathering of Coal.**—Where a stratum of rock or seam of coal reaches the surface, the exposed portion of the stratum or seam is called its **outcrop**. The coal at the outcrop of a seam is exposed to weathering, which causes it to change rapidly in appearance and character. Such outcrop coal is often reduced, by weathering, to a soft, black, sooty or clay-like deposit known as **smut**, or **coal blossom**. As this is followed back into the hill, it is found to contain small fragments of coal, and these become larger and brighter at a greater depth from the surface, until finally a continuous coal seam is found, which gradually thickens until the regular seam is reached at a depth where it is protected from the action of the atmosphere and surface drainage. In like manner, coal exposed in the open passageways of a mine is changed, more or less rapidly, by the action of water and moisture. The escape of gas and moisture from the coal often causes it to crack and crumble. The iron contained in the water of the seam or overlying strata oxidizes in the air

and stains the coal yellowish brown or red. This crumbling of the coal is called *slacking*, and takes place more rapidly when the coal has been removed to the open air. Bituminous coal slacks more freely than anthracite, and different kinds of coal undergo this action in a greater or less degree. The same weathering takes place in the outcropping of the softer rock strata, reducing a firm shale to a clay or mud seam, or a hard sand rock to a crumbling sand. Clays or shales colored black by the carbonaceous matter they contain are bleached to gray or white. Weathering also frequently produces a change in the character of the strata. For example, a hard fireclay underlying the coal often becomes soft and plastic. Limestone is frequently changed to a yellow clay; this is due to the fact that the carbonate of lime that forms the greater portion of the limestone is dissolved by water containing carbon dioxide, thus leaving only the impure clay of the limestone.

34. Avalanches, or Snowslides.—On the steep slopes of mountains, large masses of snow are often dislodged and slide down the mountainside, with great velocity, into the valley below. These avalanches are very destructive to buildings, forests, or any other objects in their pathway. They frequently carry large boulders and masses of rock with them, making them all the more destructive. The path of the avalanche is frequently adopted by the mountain torrents, and the rush of water adds to the destruction of the snowslide. The avalanche is a serious menace to the mining camp on the mountainside and to the hamlet in the valley.

35. Landslides.—The surface may be greatly modified in hilly countries by the sliding of a large mass of land from the hillside into the valley. This is especially true in the bituminous coal regions of the Appalachians, where the hills are steep and high, and where there are heavy beds of shale and clay. The slide may be caused in several ways. The strata may dip or incline toward the valley, when a bed of plastic clay may be the smooth surface down which a large mass of the overlying rock may slide. In horizontal strata, a projecting part of the hill may, when saturated with water,

lose its equilibrium and slide to a lower level. This may be brought about by the dissolving action of the percolating waters on the underlying rocks, such as limestone, or by other disintegrating or eroding agencies, which may cut away the material at the base of the hill. These landslides are sometimes of vast proportions. They are of frequent occurrence in the Rocky Mountains and in the mountainous coal-mining regions of West Virginia.

Where such a slide occurs in strata bearing coal seams, it may lead to much useless expense in attempting to mine coal from the slid mass, if it is not first recognized as such. Shale and clay beds are more likely to cause destructive landslides than such rocks as sandstone and limestone, because they absorb larger quantities of water, thus becoming abnormally heavy, and they have much less cohesive strength than the other rocks, especially when saturated with water. Many clays and shales will stand up in high vertical walls when dry that will not do so when saturated with water. They will then either slide into the valley below or slowly creep down the slope.

36. **Terraces.**—A terrace, or bench, in geology is a flat surface running along a hillside and frequently resembling an old grass-covered roadway. Terraces may be formed along the sides of a valley in several ways. Landslides, after striking the bottom of the valley, often form terraces on the side of the hill, known as **landslip terraces**; these are quite numerous in many places. **Alluvial terraces** are sand, gravel, and mud terraces formed by a stream cutting its formerly wide channel to a lower level, and leaving remnants of the former bank as terraces on the side of the valley. **Rock terraces**, common in hilly regions, are due to the unequal weathering of the different strata, the harder rocks standing out in relief as prominent ledges, and the softer rocks wearing away more rapidly. In the coal areas, the more enduring rocks are the sandstones and conglomerates, while the clays, shales, and coals are less enduring; as a consequence, coal seams are often found outcropping above a

terrace at the base of a sandstone cliff. This is so well recognized in some places that prospectors name the terrace for the coal seam that lies above it. Another clue that often aids the prospector is to note where the springs and seepage occur on the hillsides, remembering that in most cases it indicates a clay bed that commonly underlies a coal seam. The water from a coal seam frequently forms a rusty brown deposit on the surface, due to the iron that it has taken up from the iron pyrites in the coal or contiguous strata.

Where the strata are horizontal, the terraces take the form of flat table-like projections along the face of the hill, as shown in Fig. 10. Where the strata dip into the hill, the more enduring layers may project as low parallel ridges

FIG. 10

separated by the depressions worn in the softer strata, such as the clay and coal, Fig. 11.

37. Sedimentation.—As already explained, the rock strata, where exposed to the water at the surface, gradually crumble to loose fragments and fine waste. The rains and rivulets formed from the melting snows wash this fine material into the streams, which carry it to some point where it is deposited on the bottom of the stream or river. The size of the material and the distance that a flowing stream of water will carry material depends on the velocity of the current being maintained equal to its original velocity when the fine material was first taken up by the stream. A rapidly flowing river will frequently carry large stones and often

boulders, at a narrow point in the river where its velocity is very great, and will deposit them at a point where the river widens and where the velocity of the current is not so great. At any point where a stream widens and its velocity is reduced, *sedimentation* will take place; the larger particles of the sediment carried by the current will be deposited first, and the smaller particles at a point farther down the stream, the finest material being usually carried to the mouth of the river, where it is deposited in the still waters of the bay or lake into which the river discharges. The process by which sediment is thus deposited where the current of a stream is lessened is called **sedimentation.** It is one of the most important processes that give rise to geological formations,

FIG. 11

and illustrates the formation of all the sedimentary rocks previously described.

The mud and sand carried into the lake or into the sea are spread over the bottom in layers of more or less uniform thickness. A sufficient number of these layers will finally raise the bottom to the surface, thus extending the shore line farther into the body of water, where the process will be repeated, until, in the case of a lake, it is entirely filled up.

Along the ocean or lake beach, away from the mouths of rivers, the storm and tide waves act somewhat like a horizontal saw in cutting back into the land, and the retreating waves and the undertow carry the sediments into the

deeper water, where they are spread out into layers to form new rocks (see Fig. 12).

In the clear water off shore, in many places, a great many animals of different kinds grow in large numbers, and, as they die, the remains of their hard parts collect in great quantities and form beds of limestone. In some places, the

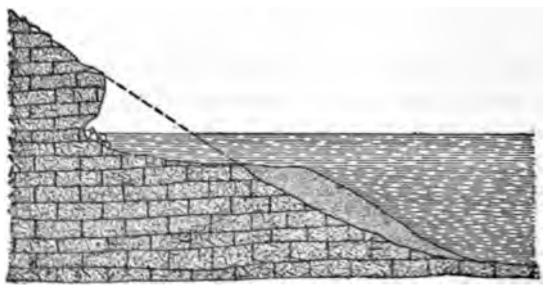


FIG. 12

limestone consists mostly of shells, constituting the shell limestone, Fig. 13; at other places, it is composed almost entirely of crinoids, from which we have the encrinal limestone; in still other places, it consists of corals, from which we get the coral limestone.

FIG. 13

38. **Extent of Sedimentary Beds.**—Sedimentary deposits, both those now forming and the sedimentary rocks already formed, are necessarily limited in extent, but some are much more widespread than others. Sand and gravel deposits extend in some places for many miles; in other places, only a few yards. The same is true of clay and shale

deposits. Limestone beds are more likely to be of greater extent than shale or sandstone, because they are formed in clear water in the open ocean and are not limited by the amount of sediment carried by the rivers or the shore waves.

39. **Induration.**—Induration means the hardening or change by which the loose sedimentary deposits of gravel, sand, and mud are in the course of time changed to solid rocks. This change is produced partly by pressure and partly by percolating waters depositing mineral matter among the grains, thus cementing them into one compact mass. The gravels form conglomerates, the sand forms sandstone, the fine mud forms clay or shale, and the fragments of shells form limestone. This process, it will be noticed, is the opposite of weathering or the disintegration by atmospheric action. Induration, or hardening, takes place generally below the point where the rocks are saturated by underground water, and where the waters are charged with mineral matter that was taken in solution nearer the surface; weathering, or disintegration, takes place largely near the surface above the zone of saturation, where the waters are charged with oxygen and acids, which aid in dissolving and breaking up minerals.

The Trenton limestone extends from the Adirondack region in New York, southwards along the Appalachian Mountains into Alabama, and westwards over large areas in the Mississippi Valley. Since the limestone beds are usually of greater extent and less subject to local changes than the other sedimentary rocks, they are valuable as **key rocks** by which coal seams and clay beds may be recognized. Thus, in the bituminous coal region of Western Pennsylvania, there are a number of coal beds, named A, B, C, etc., that are separated by beds of sandstone, shale, and limestone. A sandstone between B and C, for example, in one locality may change to shale or clay in another locality in the same basin, so that it can be of little aid in identifying the coal seams on either side of it. The several thin limestone beds, on the other hand, continue with great uniformity over a large part of the

coal field, and hence serve as guides in identifying the coal seams above and below.

40. Thinning Out of Beds.—Sedimentary deposits of all kinds generally occur in irregular lens-like masses, thicker toward the middle of the basin in which they were deposited and thinning out at the edges. Sometimes the thinning will be abrupt on one side and quite gradual on the other, the thin edges of one layer overlapping layers of an adjoining deposit (see Fig. 14). In some places, this thinning out and overlapping occurs within narrow limits on each side of the middle of the deposit, limiting the extent, in places, to a few yards. In other places, the thinning out is so gradual as to be almost imperceptible, and a thin bed of clay or shale may extend for many miles before it thins out.

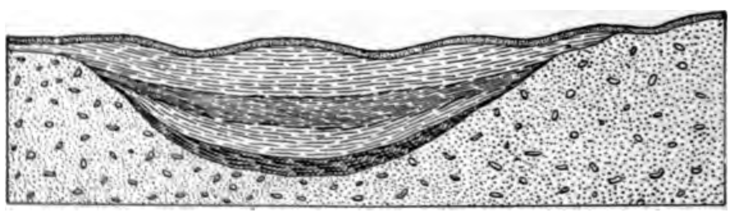


FIG. 14

Sometimes a layer of one kind of sediment, instead of thinning out and overlapping material of another kind, may gradually change in the character of its material. Thus, a current that is depositing sand in one place may deposit considerable mud with the sand a little farther on, and the mud may gradually increase in quantity and the sand decrease until finally it becomes a clay or shale bed. In many places, these changes in material will be found sometimes very gradual; in others, the change may be quite abrupt. This may be observed in coal measures, where at one point the coal seam will overlie a conglomerate, at another point a sandstone, and nearby a shale.

41. Thickness of Sedimentary Beds.—The beds of sediment are as variable in thickness as in lateral extent. One sandstone stratum may be a few inches thick, another

may be 1,000 feet; one coal seam may be a fraction of an inch thick, another may be 50 feet. When we speak of the thickness of a sedimentary bed, it is the thickness measured perpendicular to the plane of sedimentation or deposition. This thickness is vertical only when the beds are level.

42. False Bedding.—False bedding occurs where material is deposited over an inclined bed. While, commonly, sedimentation takes place in a horizontal plane, there are often local variations from the horizontal due to different causes. A strong current moving over a sandy bottom keeps depositing sand over the front slope of sediment previously deposited, producing a series of layers pitching at various angles up to 20° or more. The deposits formed in deltas may slope at a considerable angle, due to the manner

FIG. 15

of deposition (see Fig. 15). The current of the stream laden with sediment is checked suddenly where it meets the still water of the lake or bay into which it flows; hence, it drops the greater part of its burden at this point, thus building a platform into the deep water where the successive deposits on the edge of the platform have, at times, a steep slope. Lamination of this kind, as shown in Fig. 15, is known as **false, or cross, bedding,** since it is inclined to the true, or horizontal, bedding. This cross-bedding has been observed in coal. In some places it occurs in limestones, but is most common in sandstones.

43. Unconformity.—If the successive layers of sediment are deposited regularly over the preceding ones, and are parallel with them, they are said to be **conformable.** When there is an elevation of the land along the shore, the

:eviously horizontal layers are frequently tilted or inclined ͻ the horizontal, and the next series of layers deposited on .hem at a different angle, will form what is called an **unconformity.** The unconformity, which marks a break in the regularity of the layers, may consist of horizontal strata resting on inclined strata, Fig. 16; or the first series may be

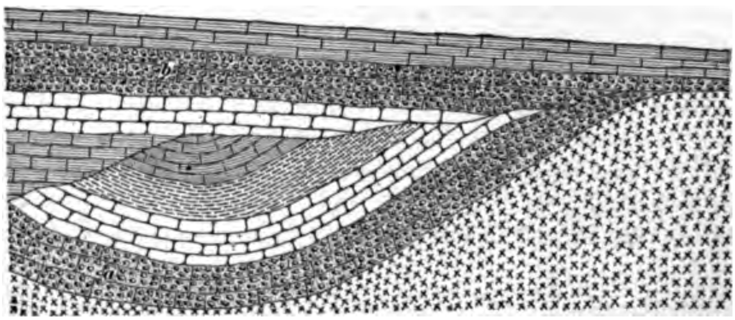


FIG. 16

inclined also; or both may be horizontal, as in Fig. 17. In the last case, the land was elevated and eroded, and sank again beneath the ocean, when the second series of deposits was formed and another elevation took place, without any tilting of the strata in any of the movements.

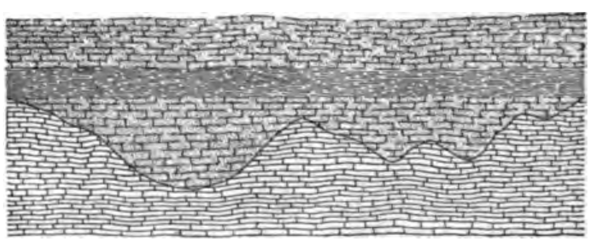


FIG. 17

44. Overlap of Strata.—If there is a slow contir depression of any area of sedimentation—for example, shallow sea bottom near the shore—for a long peric time, each new layer of sediment that is formed m; conformable to the preceding one underlying it, but

layer will overlap or extend beyond the preceding layers. This may produce unconformity at the border of the area where the new layers overlap older rocks. Thus, in Fig. 18, the water level that was first at *A A′* was raised to *B B′* and later to *C C′* by the depression of the bottom; hence, each

FIG. 18

succeeding stratum overlapped the preceding one, extending on to the former land area. By a continuation of this process, a great thickness of sediments might accumulate at *D*. The very thick sedimentary rocks along the Appalachian region were probably formed in some such way.

45. Cleavage Planes.—All rocks contain, to a greater or less extent, sets of division planes that are more or less regular and along which the material of the rock parts or cleaves most readily; these are known as **cleavage planes.**

46. Bedding Planes.—In sedimentary rocks, the principal set of these cleavage or division planes are known as the **bedding planes.** The bedding planes are the planes in which the material was deposited, and except in cases of false bedding, were originally horizontal, and are therefore always parallel to the stratification or bedding of the material. They are formed as the result of a pause in the deposition of the sediment; or a change of conditions or material deposited; thus, a layer of mud is brought down by a freshet and spread out on the bottom of the bay; a period of several months may elapse when the water carries little or no sediment, allowing the layer already deposited to become compact, so that the layer deposited by the next flood will be separated from the first by a line of parting called the bedding plane. In some shales, the bedding planes may be

only a fraction of an inch apart, while in some sandstones and limestones they may be 50 feet or more apart.

47. Joints.—Dividing the material nearly at right angles to the bedding planes are two or more sets of regular division planes known as **joints.** Where the strata lie horizontal, or the bedding planes are level, the joint planes are vertical. Sometimes the joints are at right angles to each other, or nearly so, and with the bedding planes divide the material into prismatic blocks. In some of the limestones, these dividing planes are so remarkably regular as to cause the exposure of the stone in a cliff to resemble masonry, as

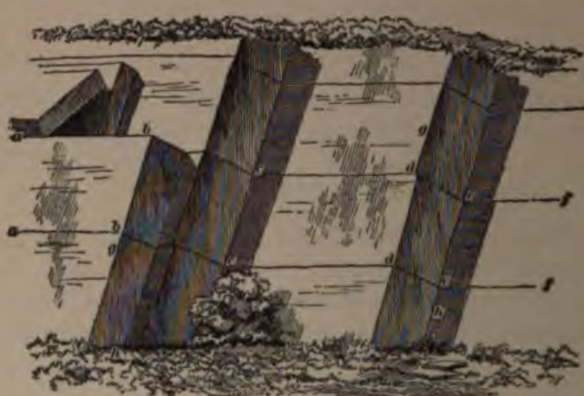


FIG. 19

shown in Fig. 19. Sometimes the joints cross one another at highly inclined angles, thus cutting the stone into rhomboidal blocks, a condition found in some slaty shales. In Fig. 19, the lines *a b*, *c d*, *e f* represent the bedding planes in which the material was deposited. The lines *c c*, *e e*, etc. represent joints that have subsequently been formed at right angles to the bedding planes. The diagonal lines *g h* and *g h* represent a cleavage that is at an angle to the bedding planes or to the joints.

Joints are confined to a single stratum, and are frequently not continuous through that. Thus, in a series of alternating limestone and sandstone strata, the joints in the limestone

stratum will not be continued into the underlying sandstone or shale, but new sets of joints occur in the underlying rocks. They may or may not be parallel with those in the upper stratum, and they are liable to be more or less numerous, depending on the character of the two rocks.

In folded rock, one set of joints commonly runs parallel to the axis of the fold or the strike of the strata; these are called **strike joints.** Another set at right angles to these are parallel with the dip and are known as **dip joints.**

The cause of joints is still a subject of investigation. In the igneous rocks, they are thought to be due to contraction in cooling. In the sedimentary rocks, they may be due partly to loss of water and partly to pressure or tension, or both. They should not be confused with bedding planes or planes of stratification.

48. Joints, or Cleats, in Coal.—Coal occurs in regular layers, or beds, like shale, sandstone, and other sedimentary rocks. Like them, the layers, or beds, may vary greatly in thickness, ranging from a fraction of an inch to several feet. Besides the bedding planes, there are other cleavage planes or partings, called *cleats*, or joints, at right angles to the bedding plane or stratification of the coal. There are usually two sets of these joints, or cleats, which are commonly at right angles, or nearly so, to each other. Joints in coal seams are more often spoken of as **cleats.** One set of cleats is usually more pronounced or prominent than the other, that is to say, the cleats extend farther in the coal and are more numerous, while the other set is short and broken. The first set of cleats, or those that are the more pronounced, are called the *face cleats* of the coal. These, almost without exception, run more or less nearly parallel to the strike where the seams are inclined or folded, and have an important bearing on the working of the coal. When the face cleats are well defined or pronounced, the coal is said to *work free* along the face cleats.

The joints at right angles to the face cleats are, what are termed in rock formations, the *dip joints*, because they are

parallel to the dip of the strata. They are called the *butt*, or *end*, *cleats* of the coal, and are sometimes referred to simply as the *joints*, *butts*, or *ends* of the coal. At times, although the face cleats are more pronounced, the coal parts more freely along the butt cleats, and is then said to work free *on end*.

Fig. 20 shows a coal bed from which the top has been stripped or removed. The bedding planes are horizontal and form the floor; the backs or face joints extend lengthwise of

FIG. 20

the picture and are vertical; the butt or end joints extend to the left and are about at right angles to the face joints.

Nearly all the bituminous coals have well-defined bedding planes along which the coal readily splits into fine layers. In the variety known as block coal, not only are the bedding planes well defined, but likewise, also, the joints, which are quite regular and cause the coal to break into cubical blocks, which characteristic gave the name to this variety. In some

cannel coals, the cleavage is quite prominent, while in others it is altogether wanting. In some localities, the cleats of the coal are quite open and in places even filled with fine sand or clay that has drained from the overlying strata; this gives rise to a vertical clay parting. At times, these vertical clay partings extend entirely across the face of a breast of coal or give the appearance of a fault. They are, however, quite thin, varying from a fraction of an inch to 3 or 4 inches in thickness. At other times, the open joints or cleats become filled with a calcareous deposit drained from an overlying limestone, and forming what are termed *spars* in the coal.

49. Clay Partings.—It is quite common for a seam of coal to be divided into two or more benches, or layers, by a thin interstratified layer of sand or clay. These thin layers are called **clay, or sand, partings.** They are often very regular and continuous over large areas, at times presenting a uniform thickness over several square miles. In like manner, there are, at times, thin layers of a calcareous parting or spar interstratified in the coal. These, however, are not regular or continuous. The clay or sand partings mark a change of conditions in the deposition of the material of the coal seam, resulting probably from an inflow of water bearing a large amount of sediment, as will be more fully described later. The spars are more probably the result of filtration into the joints and bedding planes of water saturated with lime from the overlying strata through which it has percolated.

50. Slaty Cleavage.—In mining the terms **slate** and **shale** are frequently used as meaning the same, but there is a distinction that is made by the geologist and that should be borne in mind to avoid confusion. A shale cleaves along the bedding plane, as previously explained, while a true slate, such as is used for roofing or for school purposes, cleaves along joints perpendicular to the line of pressure to which the slate has been subjected. As this pressure may be vertical or sidewise, due to contraction and upheaval of the

earth's crust, and the bedding plane may not at the time be horizontal, the lines of slaty cleavage may be parallel with

FIG. 21

the bedding plane or may make any angle with it (see Fig. 21).

DISTURBED STRATA

51. Folded Rocks.—It sometimes happens, as shown in many plateaux, that the sedimentary rocks retain their original horizontal position when they are elevated above the level of the sea in which they were formed, but quite frequently the elevation is accompanied by a folding or wrinkling process. The cause of the folding is a strong lateral pressure, but the cause of the lateral pressure is not so

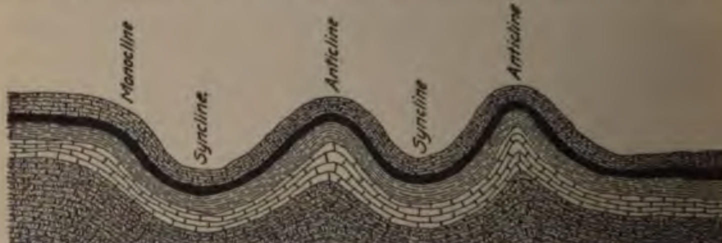


FIG. 22

clear. It is thought to be caused by the cooling and shrinking of the interior of the earth, and the outer or cool portion settling down on the smaller central mass, which would cause a wrinkling in much the same way as an apple is wrinkled on drying. The upfoldings, or ridges, have been termed **anticlinal folds**, or **anticlines**, Fig. 22, and the

downfoldings, or troughs, are called **synclinal folds**, or **synclines**; the latter form the coal basins. A single downward bending from a higher to a lower level is termed a **monocline**. Sometimes the folding may take a dome

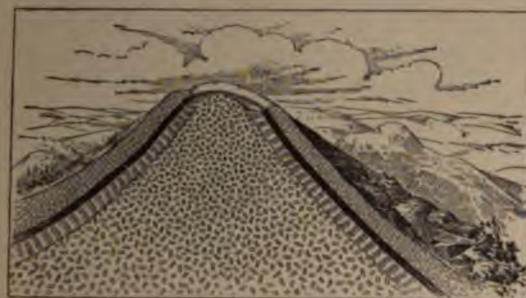


FIG. 23

shape, Fig. 23, where the strata dip away in all directions from the apex of the dome, as in the Black Hills, in South Dakota. These are called simply **domes**.

Sometimes the foldings of strata are like broad low waves with gentle inclinations toward the center of the basin.

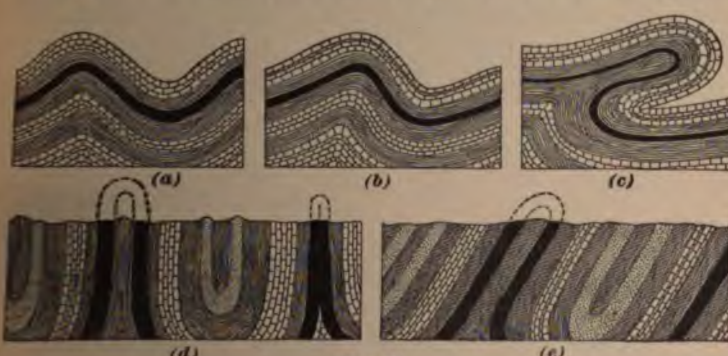


FIG. 24

Again they may be sharply compressed, as shown at (*a*), (*b*), and (*c*), Fig. 24. The folds may be symmetrical, that is, with equal inclinations on each side of the axis, or they may be quite one-sided or even overturned, as shown at (*d*) and (*e*), Fig. 24. In such a case, it is possible to have the same bed

or series of beds repeated several times; in an area of this nature, if great care is not observed, much confusion and expense in correlating the coal beds may result.

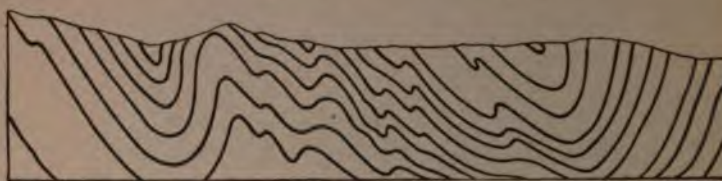


FIG. 25

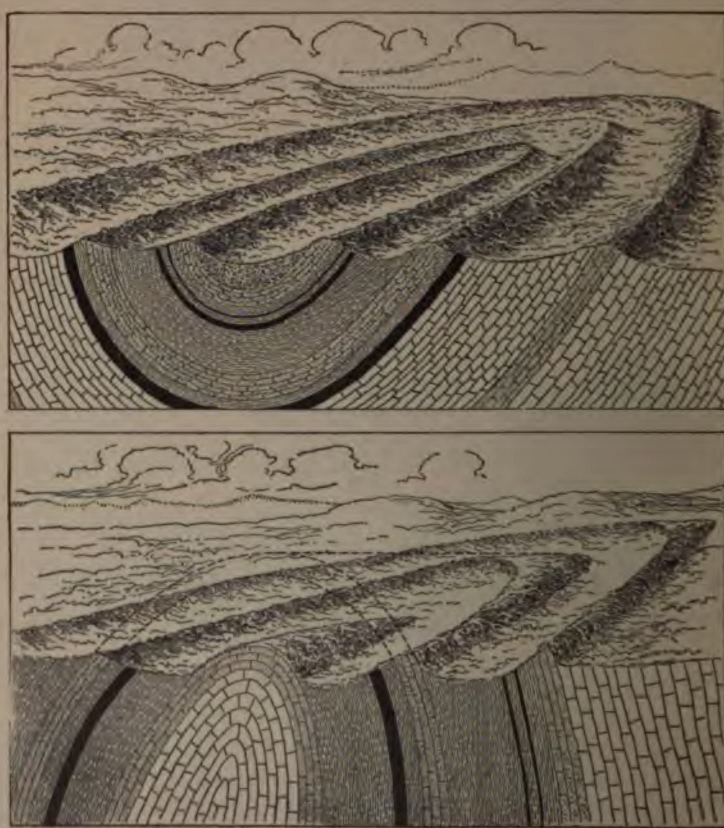


FIG. 26

52. Secondary Folds.—It frequently happens that on the sides of the larger folds there will be smaller folds with axes parallel to that of the main fold, Fig. 25. The small folds are frequently a source of expense in mining operations, because when covered with soil and weathered materials the folds cannot be detected on the surface.

53. Pitch of the Folds.—The strata, besides dipping either from or toward the axis, have also a pitch along the axis; in the synclines or basins this pitch is from the ends toward the middle of the basin, while in the anticlines it is from the middle toward the ends of the dome, as shown in Fig. 26.

OUTCROP, STRIKE, AND DIP

54. Outcrop.—The outcrop of a bed or stratum is that portion appearing at the surface, *a*, *b*, *c*, Fig. 27; it is often

FIG. 27

hidden beneath a deposit of surface soil or drift material. The outcrop of a seam on a level surface is a level line *a*, Fig. 27; it will be a straight line when the seam lies in one

plane; but when the seam is contorted or bent, the outcro] will follow the direction of the seam. The outcrop of a leve seam on a hillside is also a level line *c*, Fig. 27; it can onl; be a straight line when the hill slope is regular, as otherwis it must follow the irregularities or the contour of the hill When an inclined seam outcrops on a hillside, the line o outcrop *b*, Fig. 27, is not usually a level line, since it mus follow the irregularities of the hill.

55. Strike.—The strike of a seam is the intersection o the seam with a horizontal plane; hence, any level line in th plane of an inclined seam represents the strike of the seam The line of strike is a straight line only when the sean lies in one plane; when the seam is contorted, the line o strike follows the contortions of the seam. The outcrop o a vertical or an inclined seam on a level surface is always line of strike *a*, Fig. 27; but the outcrop of an inclined sean on a hillside is not a line of strike when the slope of the hil is irregular *b*, Fig. 27. The strike of a seam is described b; giving the direction or bearing of the line of strike.

56. Dip.—A line drawn in the plane of a seam at righ angles to its strike represents the line of dip of the seam a that point. If the seam lies in one plane its dip is the sam at all points, but if the seam is contorted or bent, its line o dip may change at every point. The dip of a seam i: described by giving the direction of the line of dip and th angle that it makes with a horizontal plane. This angle i: called the *angle of dip* or the *angle of inclination* of the seam Thus, the expression N 45° W 15° means that the directior of dip of a seam is N 45° W and the amount of dip is 15°.

ILLUSTRATION.—The relation between the lines of strike and dip ir an inclined seam is illustrated by a book lying upon a table, Fig. 28 The raised cover of the book represents an inclined seam lying in on plane. The edges *a b* and *c d* or any line in the seam parallel to then represent a line of strike. The inclined lines *a c* and *b d* or any line ir the seam parallel to them are lines of dip. In mining, the line of dip i: often called the **true dip of the seam**, to distinguish it from an; other slant line in the seam. The angle *b d e* is the **angle of dip** or the **angle of inclination of the seam.** The line *d e* is th

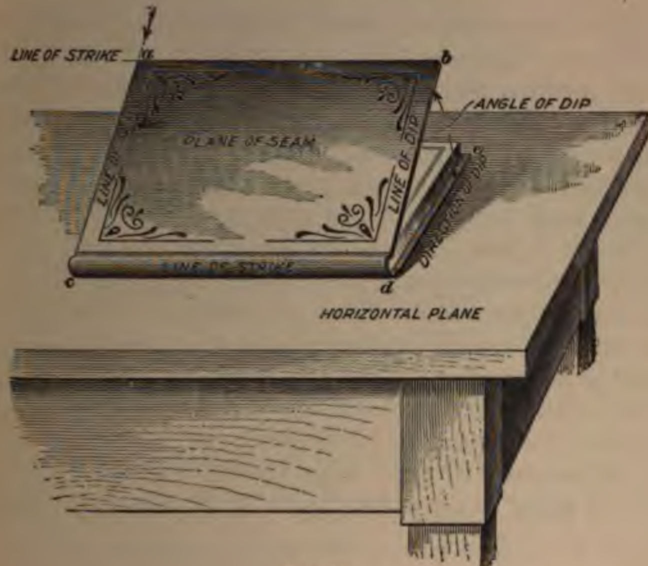

LINE OF STRIKE
b
ANGLE OF DIP
PLANE OF SEAM
LINE OF DIP
LINE OF STRIKE
c
d
HORIZONTAL PLANE

FIG. 28

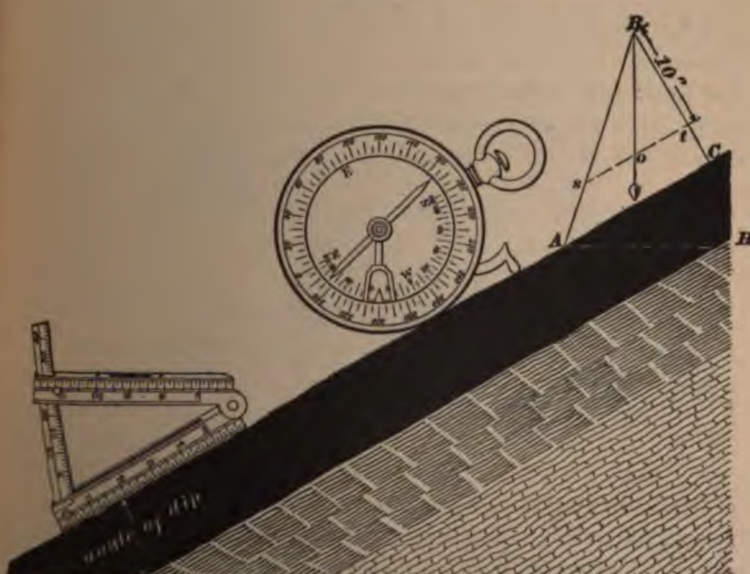

B
10"
t
C
o
s
A
H
angle of dip

FIG. 29

horizontal projection of the line of dip, and is called the **direction of dip.**

The dip of a seam is measured by a clinometer, or slope rule, Fig. 29. If these are not available, the dip may be determined by constructing a right angle out of a piece of board. (See *A B C*, Fig. 29.) A plumb-line is then suspended from the point *B* and allowed to swing freely, while the board is held in a vertical position, with one side *A C* adjoining the right angle and bearing on the stratum whose dip is to be measured. From *B* measure a distance *B t* on the side *B C* exactly 10 inches, and draw the line *t s* on the board at this point parallel to the side *A C*. When the board is in position, note the point *o* where the plumb-line crosses the line *s t*, and measure the distance *o t*. Then, one-tenth of this distance will give the natural tangent of the angle *o B C*, which is equal to the angle *H A C*, or the dip of the seam.

FAULTS

57. Definitions.—A **fault** is a break and subsequent dislocation of strata occurring in such manner as to destroy the continuity of the beds or layers. Faults are of necessity *faults of dislocation;* what are sometimes called *faults of erosion* are not true faults. In a true fault, the fracture of the strata is followed by a displacement of the strata, so that the beds on one side of the fault are lifted above or depressed below the corresponding strata on the other side of the fault. The side on which the strata occupy the higher position is called the **upthrow side**, while the other is called the **downthrow side.** The plane along which the displacement takes place may be vertical or inclined.

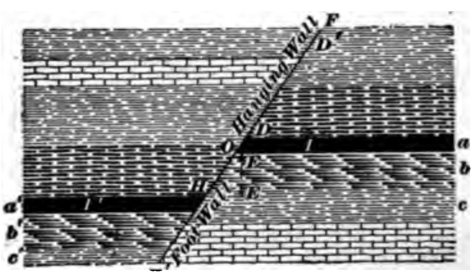


FIG. 30

Where the fault plane is inclined, the side that is above the fault line FF', Fig. 30, is called the **hanging wall**, or **roof**, and the under side is called the **foot-wall**, or **floor**, of the fault (the side to the right of the line FF' in Fig. 30). A **normal fault** is one in which the hanging, or top, wall has moved down over the bottom, or foot, wall (see Figs. 30

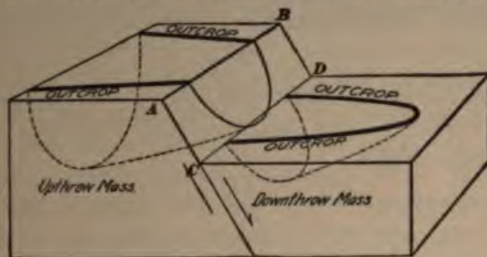


FIG. 31

and 31), a **reverse fault** is one in which the top wall has moved up over the bottom wall (see Fig. 32). A reverse fault is sometimes called a **thrust fault**, or **compression fault**. It is such a movement as would take place under strong lateral pressure, when the top, or hanging, wall would

FIG. 32

be pushed upwards over the foot, or bottom, wall. As a rule, normal faults occur in regions of horizontal or slightly inclined strata, and reverse, or thrust, faults in a region of sharply folded rocks. Hence, in a crumpled area like the anthracite coal field, reverse, or thrust, faults will be the rule.

In regions of flat-lying rocks, such as the bituminous coal fields of Western Pennsylvania and the Mississippi Valley, the faults are largely normal faults, although reverse faults sometimes occur in horizontal beds. Sometimes there is

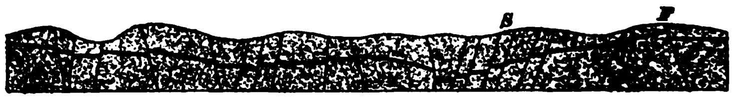


FIG. 33

but a single break, as shown at *F*, Fig. 33; and again there may be a series of breaks, as at *S*, Fig. 33, when it is called a **step fault.**

58. Overthrust.—It sometimes happens that the fault plane lies nearly horizontal and that one side is shoved out over the other for long distances. In Northern Montana, in one locality, the mountain range has been pushed out over

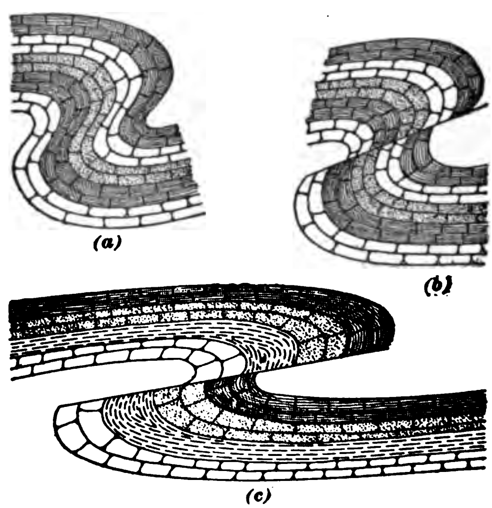


FIG. 34

the newer rocks of the plains about 8 miles. Such a fault is called an **overthrust fault**, and may take place in rocks but slightly folded or in those very highly compressed (see Fig. 34). An overturned anticline may, by continuous pressure, develop into an overthrust fault.

59. The Direction and Amount of Faulting.—The throw of a fault is the amount of vertical displacement of the beds due to faulting. Thus, in Fig. 30, the vertical distance EE is the throw of the fault. To determine the direction of faulting and the amount of throw, if the region has been developed by shafts or other openings, study the structure of the beds as shown in these openings, and determine, if possible, whether the region is one of normal or reverse faulting. If it is found to be a region of normal faulting, it is well to keep in mind the rule, "*a normal fault dips to the downthrow, but rises or pitches to the upthrow.*" Thus, in Fig. 30, if, in working on the coal seam from I, the fault FF' is met, examine carefully the walls of the fault; and if it is found that the walls dip or incline toward F', it is known that, according to the above rule, if the fault is normal, the continuation of the seam is down the incline on the opposite side of the fault. The same rule will apply on meeting the fault from the left on the bed I'; the continuation of the seam is up the pitch on the opposite side of the fault. To determine the number of feet of displacement along the fault, examine carefully the rock in the top, or hanging, wall of the fault, and see if it can be indentified with any of the layers on the hillside above the coal outcrop, or in any shaft or other opening made to the coal I. If it can, the exact throw or amount of displacement can be determined by measuring the distance between the coal seam and the layer in question on the outcrop, or in the shaft. For example, if the layer O is found, on the fault plane across from coal I, to correspond exactly with the layer D' on the outcrop on the hillside, it is only necessary to measure the vertical distance between the outcrop of coal I and the outcrop of stratum D' on the hillside to know how far H is below O—that is, how far coal I' lies below I.

In a reverse fault, the rocks are sometimes so much broken and crushed along the line of faulting that it is difficult, and at times impossible, to identify any of the layers. In such cases, it is sometimes possible to find exposures outside of the mine, on the hillsides or along the stream course, that

will give a key to the kind and extent of the fault. The striations or scratches on the wall rock along the fault plane will sometimes give a clue. The rubbing together of the rocks on the two sides of the fault will frequently polish them quite smooth and bright, when they are called **slickensides**. A hard corner or hard pebble on one side will frequently plow a deep scratch or groove on the opposite side, a phenomenon quite common on nearly all faults. It is not always possible to tell from the scratches whether they were formed by sliding down or by being pushed up; but sometimes a scratch can be found with the cause along with it—that is, with the pebble or hard part in the end of the scratch. If it is in the lower end of the scratch, it shows that the scratched side has moved up; if the pebble is in the upper end of the groove, it indicates that the scratched side has moved down. Often the layers at the fault line will be bent in the direction that the opposite strata have moved.

By one or more of the preceding methods, it is frequently possible to tell which way the coal has moved at the fault, and sometimes how far it has been displaced. Sometimes, however, all these methods fail, and it is then necessary to either drill or sink for the missing seam. Where it is not very far below the surface, it will generally be cheaper to use the diamond drill, and often one core, if judiciously located, will settle the question.

60. Slippy Coal.—It sometimes happens that, along an inclined fault plane, or sometimes even in the axis of a sharp fold, the coal, especially anthracite, becomes much broken and slickensided by friction of the pieces against each other, forming so-called **slippy coal**. It may be a source of considerable danger, as the removal of one or more of the broken pieces may start the others moving, and they will sometimes run like quicksand.

61. Faults of Erosion.—True faults, such as we have been describing, should not be confounded with clay seams and mud seams, sometimes called **faults of erosion**. These are generally caused by a stream course or glacier that has

cut a channel through the coal and that has later been filled with clay or sand. Faults of erosion are described under Irregularities in Coal Seams, Art. **67**.

Any thinning out of a coal seam or other irregularity is commonly called a fault by the coal miner, but these irregularities should not be confused with a true fault, in which there has been movement of the strata.

COAL

ORIGIN OF COAL

62. Coal has been formed and is now being formed from vegetation. The principal reason for this conclusion is the similarity in composition. Vegetable tissue consists of the elements carbon, hydrogen, oxygen, a little nitrogen, and a small percentage of mineral matter; the same elements occur in coal in different proportions. It is a matter of observation that wood exposed in the atmosphere rots and crumbles to a yellowish-brown powder, which may later disappear entirely. Some of the carbon of the wood combines with the oxygen of the atmosphere to form carbonic-acid gas. More carbon combines with hydrogen derived from the woody tissue to form marsh gas; and some of the oxygen combines with the hydrogen to form water. Possibly other gases form in small quantities until all the wood is changed to carbon (coal) or disappears in the form of gas.

If the vegetation falls into water, as in a bog or swamp, the process is different; the oxygen and hydrogen form gaseous products more rapidly than the carbon, and as a result a larger percentage of the carbon is preserved and deposited, giving the black muck of the swamp, which later is changed to coal. A large amount of marsh gas is formed by the union of carbon and hydrogen, together with smaller amounts of carbon-monoxide gas and some carbon-dioxide gas. These gases at first bubble to the surface of the water and escape. This process may be observed taking place at

any time in stagnant pools, where the gas is seen to rise in bubbles from the deposited vegetable matter lying at the bottom of the pool. As the vegetable matter becomes covered with later accumulations, the chemical changes continue, but the gases formed are unable to escape and are entrapped in the pores of the forming coal. These gases form the occluded (hidden) gases of coal seams. This process, in its various stages, may be observed today in the formation of peat bogs and the metamorphism of the peat, forming coal. The conclusion is reasonable, therefore, that coal is a product of vegetation.

Other reasons for this conclusion are that the coal in many instances retains the cellular structure of the vegetation from which it was formed, and the rocks above and below it contain many fossil impressions of the leaves, wood, etc. of the plants of that period. A substance closely resembling anthracite has been produced from wood in the chemical laboratory by exposing vegetable material to the action of moisture and heat under pressure.

63. Accumulation of Material.—The vegetable material of the coal beds may have accumulated, much as it does today, by being carried by streams or currents into lakes or other bodies of water, like the great raft on the Red River, in Louisiana, or the accumulations in some of the delta

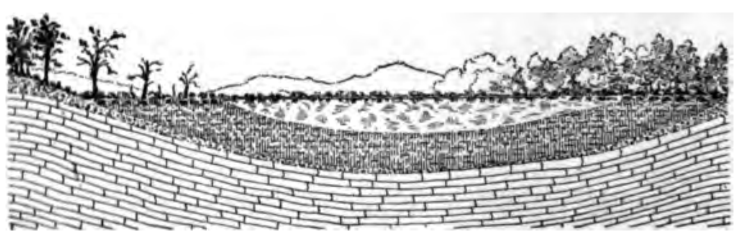


FIG. 35

deposits and river swamps; or by growth and accumulation in still water—in bogs or swamps. In northern climates, the small lakes and ponds are frequently filled largely with the remains of a single plant known as the *peat plant*, a species of moss. This plant grows on the surface of the

water, and may float out some distance from shore. New plants grow on the top, and the dead plants drop from the under side to the bottom of the lake, as shown in Fig. 35, until the growth from the shores meets in the middle of the pond. The vegetable remains accumulate on the bottom and form a quaking bog, which eventually fills the entire basin. If the whole mass be now submerged or covered with a layer of mud or sand, we have all the conditions necessary for the formation of a coal bed the size of the original lake (Fig. 36) or often larger. At times, the bog climbs several feet above the level of the lake, drawing up the water by capillary attraction, and growing back long distances from the pond; this is called a **climbing bog.** One of the largest vegetable accumulations now in progress is

FIG. 36

that in the great Dismal Swamp region of Virginia, which has been formed by the accumulation, through a long period of time, of the remains of the different kinds of vegetation that grow in it. It is now many feet in depth and hundreds of square miles in extent. Should this area be submerged and covered with other sediments, the conditions would apparently be favorable for the formation of a coal bed of large dimensions.

Where the vegetation has drifted together, as in delta deposits, there will generally be more or less mud and sand with it, as currents that carry much driftwood carry sediment also. It is possible that in some such way the impure coals, or those high in ash, were formed, as were also the carbonaceous shales.

64. Clay or Sand Partings.—In the formation of a coal seam, it is easy to understand how a change of geological conditions in any part of the area tributary to the basin

where the coal is forming may cause a large amount of sediment to be carried into the basin and deposited as a layer of sand or clay over the entire area, interrupting, for a time, the accumulation of the coal-forming material and causing, as previously explained, the formation of a clay parting in the coal seam. Sometimes, there will be more or less intimate intermingling of the mud and coal, forming layers of bony or slaty coal. The accompanying sections, Figs. 37 and 38, which are drawn from accurate measurements of different

Fig. 37

coal seams, show both the uniformity and the variation in the number and character of the partings in the same and in different basins. One of the most striking examples of widespread uniformity of structure is found in the Pittsburg coal seam, from which a number of sections are given in Fig. 37 from widely separated localities. It will be noticed that very thin clay seams exist through all the sections in the same relative position and of nearly the same thickness. The different parts of the bed keep their characteristic

structural features so well that they are at once recognized by the miners anywhere in the basin. The regularity is more marked in the lower part of the seam than in the upper part.

65. These clay and shale partings indicate a change in the physical conditions during the accumulation of the vegetable deposit. Thus, during a period of quiet, the pure

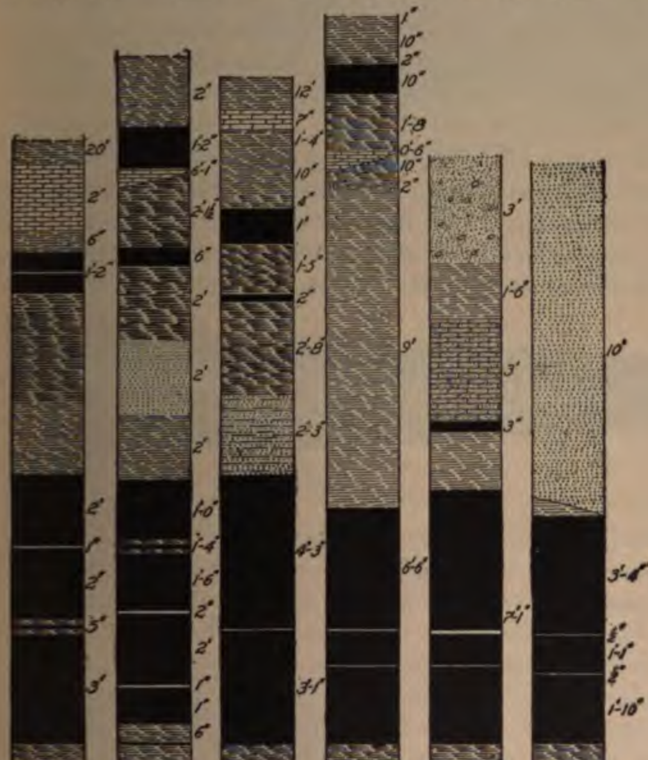


Fig. 38

vegetable matter grows and accumulates until it is interrupted by an inflow of muddy waters during a freshet, and a layer of mud or clay is deposited. Finally, the water of the bog or swamp clears and the pure vegetable matter begins to accumulate again, until the next flood of muddy waters forms another layer of clay. This alternation of mud and

vegetable deposits continues until there comes a depression of the whole area, and an inflow of deeper waters, in which accumulate sediments free from vegetation, as a bed of sand or mud, which is later changed to sandstone or shale. In course of time, the water again becomes shallow from the accumulated sand and mud, vegetation begins to flourish, and another coal seam begins. This process will continue as long as the conditions are favorable, until in some instances a thickness of several thousand feet of rock strata and included coal seams is formed. The whole series might be called *coal measures*.

Layers of sand or sandstone sometimes occur in the midst of the coal beds, Fig. 39, due to a deposit of sand having been brought into the coal swamp during a freshet. The sand or sandstone layers are liable to more sudden changes in thickness than the clay seams.

FIG. 39

66. Coal Basins.—It is customary in speaking of the different coal areas to call them **basins**, due to the fact that the coal seams commonly lie in basin-like depressions or synclines. The word is more accurately used, however, to designate the real basins or depressions, of which there may be several in a single coal field. Sometimes the coal bed is cut out entirely between adjoining basins, but sometimes there is only a thinning out of the bed on the border of the basin. The coal is generally thickest in the middle portion of the smaller basins.

A coal basin sometimes covers the entire area in which the vegetation accumulated; but frequently it is a synclinal area bounded by two anticlines, several of which may occur within the limits of the original coal fields, Fig. 25. In such cases, the basins are secondary formations caused

by the folding of the strata and the coal beds. The anticlines separating these basins may or may not have been eroded later. Thus, in Western Pennsylvania, the same coal seams may be traced through several adjoining basins. There is frequently no basin form or depression on the surface of the area; sometimes, in fact, the opposite is true. The basin refers to the original position of the underground strata. At times, the coal seam still occupies the original basin, but the strata overlying the coal are often thickest in the middle of the basin. The accompanying cross-section of a coal basin, Fig. 40, will illustrate this.

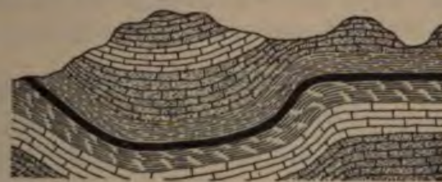


FIG. 40

LOCAL IRREGULARITIES IN COAL SEAMS

67. Besides the faults already described, and besides the thinning out of the bed at the edge of the basin, there are many other irregularities in coal seams, more or less local in occurrence, that often cause considerable trouble and expense and sometimes result in loss of life.

68. Clay or Rock Seams.—In the mining of coal, there is sometimes encountered a wall of clay or sand cutting entirely through the coal seam. When the miner strikes one of these seams, he may be puzzled for some time, as the coal has apparently disappeared, and he may not be able to tell at first that he has not met a fault. Generally, this clay seam will be only a few feet, sometimes only a few inches, thick, but occasionally it may be 100 feet or more. This clay seam may represent only a small fissure or crevice in the coal seam, that has been filled with clay or sand, as

FIG. 41

shown in Fig. 41; or it may be an old stream channel that has cut out the coal and was later filled with sediment, Fig. 42. This channel may have been cut through the coal in the same period in which the coal was formed, or it may have been cut through in comparatively recent times. The most dangerous and troublesome of these channels are

FIG. 42

those that were formed at or just previous to the glacial period, and were filled up and covered over by the glacial drift, as shown at the pothole in Fig. 9. The trouble arises from the accumulation of quicksand, water, or plastic clay that may occur in the channel, and that, as soon as tapped by the miner, run in and flood the mine, often with disastrous results.

69. Dikes.—In the vicinity of volcanic regions, coal seams will sometimes be intersected by dikes more or less vertical, the fissures forming them being filled with igneous rock. These dikes, like the clay seams previously mentioned, are generally but a few feet, or at times only a few inches, in thickness, and formed of firm, hard rock. In working the mine, the meeting with one of these dikes does not involve any greater expense than that of cutting through that thickness of hard rock. Sometimes the coal will be metamorphosed to natural coke or anthracite for some distance on each side of the dike, the distance varying with the size of the dike and the temperature of the intruded lava.

70. Rolls, Swells, Pinches, Hogbacks.—In the floor and roof of the coal many inequalities are found that are variously named in different localities. The inequalities in the floor may be due to the irregularities of the surface on which the vegetable matter was originally deposited, and may form low ridges, or **swells, horsebacks**, or **rolls.**

The term **roll** in some places applies likewise to similar prominences in the roof. The term **pinch** is commonly used when the floor and roof come together so as to nearly cut out all the coal. Fig. 43 shows a roll with a pinched coal bed at the top. These inequalities are marked features in many coal fields, and cause considerable expense both in

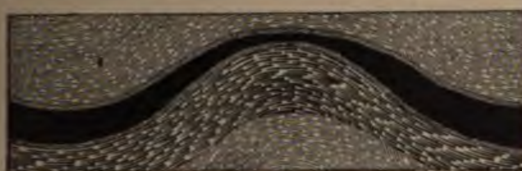


FIG. 43

cutting through them and in their interference with the drainage and haulage of the mine, to say nothing of the diminished amount of coal. The sharper ridges or rolls in the floor or roof of the coal are referred to in some localities as **hogbacks.**

71. Bells.—A special structure known as a **bell,** sometimes found in the roof, is a source of danger. This consists of a bell-shaped mass that appears to lie on top of the coal seam. It is of the same material as the surrounding rock, and is similar in appearance. Bells are apparently petrified stumps of trees that part freely from the surrounding material, and drop out of the roof without warning when the coal is removed from beneath. The suddenness with which they drop out adds to the danger, as often a blast or sudden shock in the mine causes them to fall. Boulders or pot bottoms are large boulders in the roof protruding into the coal, and are dangerous for the same reason as the bells. Concretions somewhat similar to bells are not infrequent in the shales and sandstones of other formations than coal, but these generally have a rounded form.

72. Sulphur Balls.—In many mines, sulphur balls form an important and annoying feature. Sulphur balls are concretions formed by the gathering of iron sulphide into more

or less rounded nodular masses. Nearly all deposits, whethe coal, mud, or sand, contain more or less iron in different forms The same principle of segregation that causes the clay ston to form in the clay bed, and the flint nodule in the chalk bed causes the iron to form sulphur balls in the coal bed.

THE UNDER CLAYS

73. Nearly all coal seams of any considerable exten are underlain by a bed of clay, known as **under clay,** o **fireclay.** The under clay of coal seams is of two kind: a smooth plastic clay, known as soft fireclay, and a har non-plastic clay known as flint clay, or hard firecla Hard under clays, that require a good pick to mine them often change to a soft plastic clay when wet. The unde clay, or fireclay, of the coal beds is one of the best roc materials for holding water. The under clay of a coal sean represents the soil in which part, at least, of the vegetatio grew. Fireclay was formed because vegetation tends t extract the soluble materials in the clay, such as lime, iron and the alkalies, the absence of which distinguishes a firecla from common clay. In some places, the roots and stump of the fossil coal plants occur in large numbers in th under clays; and in some places, the roots in the under cla are attached to the trunk that has changed to coal in the coa seam above. Similar clays are found frequently underlyin bogs and swamps of the present day, and under condition probably similar to those in which the fireclays of the coa seams existed.

74. The clays are important commercial products in th bituminous coal areas of Central and Western Pennsylvani and the adjoining states. The clay best known and mos extensively used in Western Pennsylvania and Ohio is tha underlying the Lower Kittanning coal and known as th Kittanning clay, but the Brookville, Clarion, and Freepo clays are important commercial products. The relation o some of these clay deposits to the coal seams and to eac

other in the Beaver River region of Western Pennsylvania is shown on the accompanying section, Fig. 44.

While the general mode of occurrence is a bed of clay underneath the coal, there are a great many fireclay deposits, and some of the best ones, too, that have no coal on top of them; while, less commonly, coal beds occur without any fireclay underneath. There is very little fireclay, none of commercial importance, underneath the anthracite seams.

The clays vary greatly in thickness and purity, but there seems to be no definite relation between the thickness and purity of the clay and the thickness of the coal. Where the

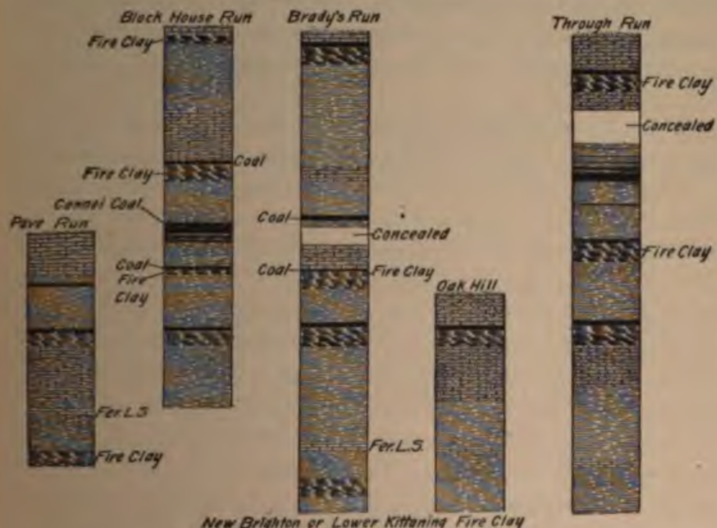


Fig. 44

fireclay occurs without any overlying coal seam, it may have been fireclay at the time it was deposited, and the deposit covered by sand or mud before the vegetation had time to grow; or, in some cases, the vegetation may have been there, but was all oxidized or carried away by erosion before it could be covered with sediment. The occurrence of fireclay and coal together sometimes makes it profitable to mine them both where neither could be worked profitably alone.

VARIETIES OF COAL

75. Coal may be variously classified from different standpoints, but the most common classification, based on the percentage of carbon, is that of *peat*, *lignite* or *brown coal*, *bituminous*, and *anthracite*. As there is a considerable gap between typical anthracite and a bituminous coal, it is customary to use the terms *semianthracite* and *semibituminous* for the intervening grades. Anthracite contains very little volatile matter and a high percentage of fixed carbon; while bituminous coal contains more volatile matter and less fixed carbon. Lignites contain more volatile matter and less fixed carbon than bituminous coal, while peat contains a still larger amount of volatile matter and a smaller percentage of fixed carbon.

76. Peat is the name given to the first stage of the carbonization of vegetable matter. It may not be advisable to class it as a coal, as it can hardly so rank in the United States. The term peat is applied to the mass of partially carbonized vegetable matter of bogs and swamps. It is sometimes used in a restricted sense as applying only to the pulpy remains of the peat plant or moss, and the term *lignite* is applied to the swamp product composed of woody fiber. The former use of the word, however, in which it signifies an intermediate grade of carbonization between wood tissue and lignite, is common.

Peat is not used as a fuel in the United States, although numerous attempts have been made to do so at different times. The chief drawback is its low calorific, or heating, power, due chiefly to the high percentage of water it contains: because so much of its heating power is required to vaporize the water contained in it before the remaining heat is available. It is used in the United States to some extent as a fertilizer in compost heaps. It has been employed as a cheap packing material for steam pipes, boilers, and buildings, and for making coarse mats. It occurs in vast quantities in the Northern United States and Canada, in the many small glacial lakes that it has filled and is filling today, forming bogs and meadows.

77. Lignite is the name commonly used for the next higher stage of carbonization above peat. The term has been used with different significations by different writers. It has been used by some as a name for all the coals that have been formed since the Carboniferous age; but this use of the term is dying out and it is now more properly applied to the brown coals. Lignite, or brown coal, has a higher percentage of fixed carbon and a lower percentage of water, and hence greater fuel value, than peat, but is much inferior to bituminous coal in heating value. It stands intermediate between peat and bituminous coal. Lignite has a more compact structure than peat and a dark brown to nearly black color, but while the color of the coal is black, its powder is brown. It is inclined to air-slack and crumble rapidly on exposure to air. Lignite has been used as fuel in limited quantities in Virginia, North Carolina, Alabama, Mississippi, and some of the western states, and in much larger quantities in Germany.

78. Bituminous coal is that stage of carbonization next above lignite. It has a decidedly black color and black powder, and rarely shows to the naked eye the vegetable structure, such as appears in peat and lignite. It has a lower percentage of oxygen, hydrogen, and water, a higher percentage of fixed carbon, and hence a greater fuel value, than either of the preceding classes. Bituminous coal is the most abundant and widespread of all coals. The bituminous coals include a number of well-marked varieties. A **caking, or coking, coal** is one that softens, swells, and runs together when heated in a closed oven, away from air. This operation is called *coking*. The product, called **coke**, after cooling, is hard and brittle, having a light porous texture caused by the escape of the gas from the semifused mass during the heating. A *non-coking coal* burns freely, with a bright flame, to an ash without fusion, and is frequently called a *free-burning coal*.

79. Cannel coal is a variety of bituminous coal very rich in gaseous products. It is easily kindled, burning with

a bright yellow flame like a candle, which fact gives it its name. Cannel coal differs in appearance from other coals in having a dull resinous luster, a uniform texture, and by frequently breaking with an irregular (conchoidal) fracture. It is a valuable gas coal and is desirable for open-grate fires because of its bright, cheerful flame.

80. Block Coal.—In a few localities in Indiana and Ohio, where the cubical jointing of the coal is especially well developed, the coal breaks into fairly large lumps or blocks; hence, the term **block coal** is used to distinguish it. Block coal is best developed at Brazil, Indiana, where there are two beds known, the *upper* and the *lower* block coal. The coal cleaves or splits quite readily, parallel with the bedding, but breaks with great difficulty across the bedding. It is mostly a non-coking coal. It burns freely with a bright yellow flame, and hence makes an excellent grate coal.

81. Gas coal is a coal high in volatile matter that can be driven off in the manufacture of illuminating gas. Cannel coal is higher in gaseous compounds than any other variety, and while it is not a valuable gas coal when used alone, it becomes so when mixed with a coking coal.

82. Smithing coal is a coking coal that is free from sulphur. The small percentage of sulphur in so many of the bituminous coals makes the iron brittle and injures its strength and welding properties; hence, the blacksmith is often compelled to obtain his coal from a great distance in order to get one free from sulphur.

83. Steam coal is a coal that burns with a long flame and high heat, making it desirable for use under boilers for producing steam. It is of greatest importance to steamships, where great steam-producing quality is required and the bulk of the fuel is an important item. The best steam coals in the United States are the semibituminous coals from the eastern outlying basins of the Appalachian field. Those from the Cumberland, the Pocahontas, and the Central Pennsylvania regions rank among the best steam coals of the United States.

They have more volatile matter, hence a longer flame, than the anthracite; and a higher percentage of fixed carbon, hence a greater source of heat, than the common bituminous coal.

84. Anthracite.—Anthracite has a much higher percentage of fixed carbon than any other coal. It generally has a bright luster, uniform texture, conchoidal fracture, and high specific gravity (1.57). It ignites slowly, and burns at a very high temperature. It is not a long-flaming coal, but burns with a short, pale blue flame, and is free from smoke, making it a desirable domestic fuel. It is also used extensively for metallurgical purposes, because of its high heating and non-coking qualities. Anthracite is supposed to be a metamorphosed form of bituminous coal, much of the volatile matter having been driven off in the process of folding and crumpling the rock strata in which it occurs; or in some localities, as in Colorado and New Mexico, the metamorphism is produced by heat from dikes of igneous rocks protruded through the coal.

Semianthracite and semibituminous coal stand intermediate between anthracite and bituminous, the first having from 7 to 12 per cent. volatile matter, and the second from 12 to 18 per cent. They include some of the most valuable steam coals, and are in great demand in the war vessels and merchant marine.

85. Asphaltic Coals.—Besides the varieties of coal described, there are some of quite different character that occur in limited quantities in a few places. They occur in veins, filling fissures and cavities in the rock, and are supposed to be derived from asphalt or petroleum from which the lighter hydrocarbons have been driven off. They are of limited commercial importance when compared with the true bedded coals.

Petroleum and natural gas are closely related to the coals in several ways. They are compounds of carbon, hydrogen, and oxygen, but in different combinations from what exists in the coals, the elements being combined in the forms known as hydrocarbons. They are probably distillation products from vegetable or animal remains.

GEOLOGICAL AGE OF ROCKS

86. The history of mankind is a continuous record, is divided for convenience of study into different peri such as ancient, medieval, and modern. Geological tory, or the history of the earth as a globe, has been tinuous, but for convenience of study and reference divided into different periods (see Table I). The his of the human race is preserved in books, manuscri inscriptions, and implements of man's handicraft. history of the earth is recorded in the rocks, the st forming the rocky leaves of the great stone book of rec The leaves were originally laid down in the order in wh they were made, the oldest at the bottom and the newest top. The kind of material in the rocky leaf, the texture structure of the material, the kind and character of fossils occurring in it, are the letters and language by me of which the geologist reads the history of that time. finds that each rock stratum has fossils different from th in the strata below or above it, which fact gives him a to the determination of the relative age of broken and d turbed strata whenever they are found.

87. Fossils.—The shells, skeletons, and other hard pa of plants and animals that fall in the mud and sand depos are covered by later deposits and preserved as **fossils.** T entire substance may be preserved, or this may be destroy by the percolating water and only the imprint or cast p served in the rock as a fossil. The imprint of a leaf or ste of a plant may be preserved in the same way; also, the fo prints of animals, rain drops in the mud, or ripple marks the sand, caused by waves on the shore. These imprints marks of former life that are preserved in the rocks as f sils record the history of the time in which the sedime were formed. Thus, from the strata underlying the c

		Niagara	Clinton	Shale, limestone, and iron ore	Age of invertebrates—mollusks, trilobi corals, sponges
			Medina	Sandstone and shale	
			Oneida	Conglomerate and sandstone	
	Ordovician	Trenton	Hudson River (Cincinnati)	Shales and limestone	
			Utica	Shales	
			Trenton	Limestones, marbles, and shales The Black River limestone Bird's-eye limestone	
		Canadian	Chazy	Limestones and marbles	
			Calciferous	Calciferous sandstones, magnesian limestones	
	Cambrian	Potsdam	Upper	Sandstone and quartzite	
		Acadian	Middle	Limestones, shales, sandstones	
		Georgian	Lower	Limestones, shales, sandstones	
Proterozoic	Precambrian: Algonkian	Keweenawan		Alternating series of sandstones, conglomerates, and volcanic rocks	
		Upper Huronian Lower Huronian		Metamorphic and igneous—granites, gneiss, schists, quartzites, marbles, limestones, slates, phyllites, iron ores, and jaspilites	
Azoic (Without life)	Archean	Laurentian		Igneous and metamorphic only Granite, gneiss, and other crystalline rocks	

*European Divisions

beds near Pottsville, Pennsylvania, some years ago, a slab of rock was removed that showed ripple marks made by the waves, rain prints, and animal footprints (see Fig. 45). From this, one could read that a shallow sea bottom had been recently exposed, as shown by the fresh ripple marks; that a large animal walked over it while it was still soft; that shortly after there was a shower of rain; and then the area was depressed below the sea level again, and covered with sediment that preserved the record until it was opened and read by geologists many years later.

FIG. 45

The kind of the fossils indicates whether sediments were formed in the sea or in lakes, whether the sea was deep or shallow, whether the climate was warm or cold, and, as already stated, the relative age of the rocks.

As certain plants and animals are today characteristic of certain countries or sections of countries, so certain fossils of plants or animals are characteristic of certain periods in the geological history of the earth.

88. The boundary lines between the periods of political history are indefinite and cannot be exactly located. So, also, it is with the boundary lines between the divisions of geological time, which is divided into *eras*, *periods*, *epochs*, and *stages*, as shown in the chart, this division being usually based on a characteristic form of life or a particular kind of rock, which distinguishes the given geological time more or less definitely. There are a great many classifications of geological history similar to the one given in Table I,

which, however, gives the division commonly used in the United States.

The student should become familiar with the names of the eras and periods, as these are general in their application; but for detailed information on its epochs and stages, reference must be made to the extensive geological reports of the several states.

The table given should be read from the bottom upwards, to correspond with the order of the deposition of the rocks.

89. The Precambrian Period.—All rocks older than those in the Cambrian period at the bottom of the Paleozoic, as shown in Table I, have no well-preserved fossils, and most of them are metamorphosed and highly crystalline. They are commonly spoken of as the Precambrian rocks, but are in some places further subdivided into the Archean and the Algonkian, and the latter subdivided into several periods in the Lake Superior region. While these rocks have no well-preserved fossil forms, they contain indications that life of some kind was very abundant, even in that early time. The record is obliterated to such an extent that we cannot read the details. The soft parts of animals are rarely preserved as fossils, and the life of this period may have had no hard parts. When rocks are much metamorphosed by folding and crystallization, as the Precambrian rocks are, any fossils that may have been in them would likely be destroyed. While fossils do not occur in these Precambrian rocks, there is good reason for thinking that both animals and plants existed then, because the deposits of graphite, limestone, iron ore, and black shale are all probably the result of life, since we know of no way in which these substances can be formed in large quantities, except by plant or animal remains, either directly or indirectly. The most extensive iron-ore beds of the world occur in the Precambrian rocks, so that it is sometimes called the *iron age*. Granites, syenite, gneisses, schists, slate, marble, and quartzite are the prevailing rocks.

90. The Cambrian and Silurian Periods.—The sediments formed during the early part of Paleozoic time in the

Cambrian and Silurian periods contain fossil remains of a great variety of animal forms. Yet, while the forms are numerous and varied, they all belong to the lower types of life: the invertebrates, or animals without a backbone,

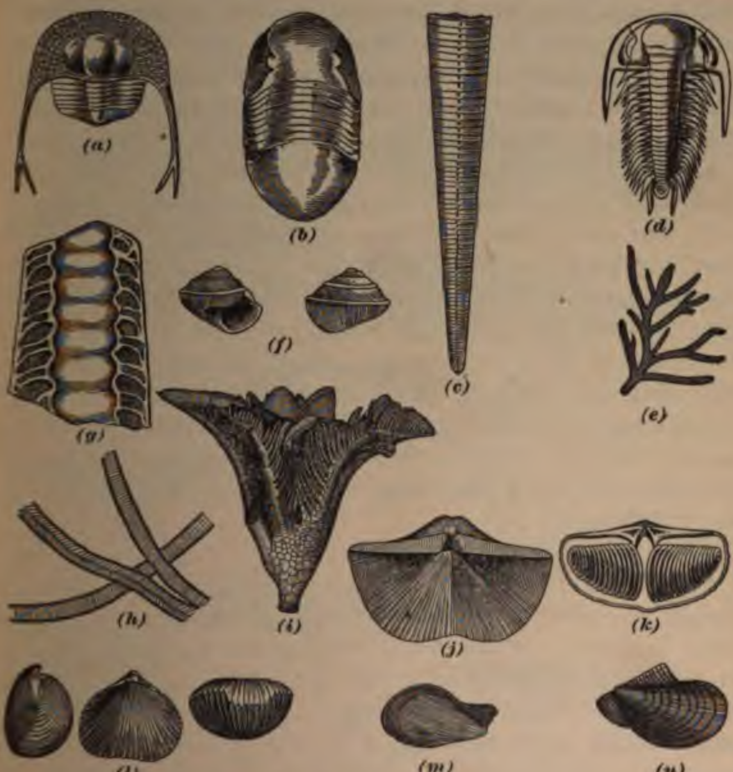


FIG. 46. SILURIAN FOSSILS

(*a*), Trilobite; (*b*), Trilobite; (*c*), Orthoceratite; (*d*), Trilobite; (*e*), Silurian plant; (*f*), Gasteropod; (*g*), Orthoceratite; (*h*), Worm tracks; (*i*), Crinoid; (*j*), Brachiopod (Spirifer striatus); (*k*), Spirifer striatus; (*l*), Brachiopod (Rhynchonella); (*m*), Lamellibranch; (*n*), Lamellibranch

mollusks, crinoids, trilobites, and kindred forms of sea animals abound, but no land plants or land animals, or animals of any kind with a backbone, are found. Some of these forms are shown in Fig. 46.

Limestones, marbles, sandstones, shales, slates, salt, and gypsum are the prevailing rocks. The rocks of this period abound in many economic products, such as petroleum and natural gas in Ohio, Indiana, and New York; lead ore in Wisconsin, Iowa, Illinois, and Missouri; iron ores all along the Appalachian Mountains; roofing slate in Pennsylvania; marble in New England, New York, and Pennsylvania; manganese, zinc, and other metallic ores in different states. Besides the petroleum and natural gas, there is considerable carbonaceous material in these rocks, but the carbon compounds of the organic remains are mingled with such quantities of mud and sand that they do not form beds of coal, but form, instead, deposits of black shale similar to that overlying the coal beds. The resemblance to coal is so strong that much time and money have been wasted digging in them for coal. Black shale overlies coal seams in the strata of the Carboniferous period, but there are a great many extensive beds of black shale in the Devonian, Silurian, Ordovician, Cambrian, and even Precambrian rocks, which do not contain coal and never did. It is advisable to determine the age of the black shale before spending much time exploiting it for coal.

91. The Devonian Period.—During the Devonian period, vertebrate animals made their appearance in the form of fishes. A few fossil fish remains have been found in the Silurian strata, but they did not become abundant until the Devonian period, when the seas swarmed with them. They were different, it is true, from the fishes living today, yet they were vertebrates, and many of them of large size. They are known as ganoids and have horny plates arranged in regular order in place of scales. Land plants in limited numbers also occurred as forerunners of the dense vegetation of the following period. The mollusks and other invertebrate forms were still abundant, but the species were different from those in the preceding period. Fig. 47 shows some fossils of the Devonian period

In the Eastern United States, along the Appalachian range, the rocks of the Devonian period consist of shales and sandstones, with a few layers of limestone. In the Mississippi Valley, the limestones are more abundant, with considerable black shale, and the sandstones are absent. In Western Pennsylvania and adjoining portions of New York, Ohio, and West Virginia, large quantities of petroleum and natural gas are stored in the Devonian sandstones. There are several

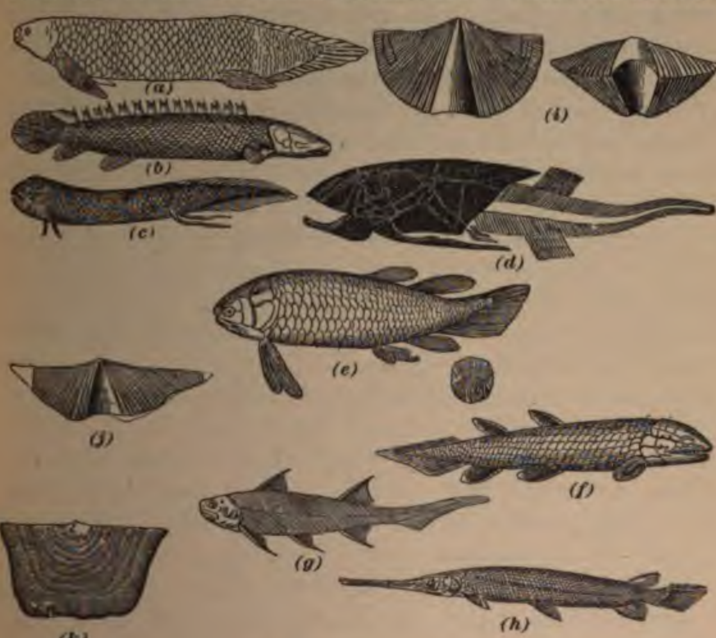


FIG. 47. DEVONIAN FOSSILS

(a), Ceratodus Fosterii; (b), Polypterus; (c), Lepidosiren; (d), Coccostens decipiens; (e), Holoptychius nobilissimus; (f), Osteolepis; (g), Diplacanthus gracilis; (h), Lepidostens (gar fish); (i), Brachiopod (Spirifer); (j), Brachiopod (Orthis Livia); (k), Brachiopod (Strophomena rhomboidalis)

layers of these *oil sands*, but they are not everywhere oil-bearing. The oil and gas are probably produced from the plant and animal remains deposited with the sediments. There are thin seams and small pockets of coal in the Devonian rocks in a few places, but none that have much commercial value.

92. Carboniferous, or Coal, Period.—With the Carboniferous period began the first of the great coal-making epochs. The early part of the period, known as the Lower or Subcarboniferous, was marked in the Mississippi Valley by extensive beds of limestone associated with a very little shale and sandstone. In the Northern Appalachian district the sediments of the Lower Carboniferous period consist of a heavy bed of red shale, known as the Mauch Chunk red shale, and a thick stratum of sandstone, the Pocono. The eastern sediments do not contain many fossils, but the limestone deposits of the Mississippi Valley are very rich in marine fossils, such as crinoids, corals, and brachiopods. These fossils have special interest to the coal prospector, as they indicate the strata that underlie the coal beds, and in and below which it is not wise to seek for coal.

The lowest stratum in the coal measures is in many places a coarse conglomerate, grading into sandstone in some localities and containing local deposits of shale, clay, and coal. In Pennsylvania, it is known as the Pottsville conglomerate; and in the anthracite region it is composed of coarse pebbles, with an increasing proportion of sand toward the north and west. Through Central and Western Pennsylvania, it is a massive white, gray, and yellow sandstone that contains numerous white quartz pebbles scattered through it. Through the Mississippi Valley, the stratum is in places a conglomerate, in most places a coarse sandstone with a few pebbles, and in some places contains shale, clay, and coal. It is called the Mansfield sandstone in Indiana, and the Millstone grit in Illinois. It varies in thickness from a few feet to several hundred feet. It rests unconformably on the Lower Carboniferous limestones and shales in Indiana.

Overlying the Pottsville conglomerate, in the Eastern and Central United States, is a series of limestones, shales, sandstones, clays, and coals, which together make up the coal measures. This series of rocks varies greatly in thickness, and also varies greatly in the number and thickness of the individual coal seams.

TABLE II

COAL MEASURES OF WESTERN PENNSYLVANIA

Compiled by Baird Halberstadt, Pottsville, Pa.

Name	Numbers	Coal Beds in Each Series and Their Thicknesses
Greene County group, 300–400 feet	XVII	Windy Gap (1′ 0″—2′ 0″), Nineveh (1′ 0″), Dunkard (1′ 0″—1′ 3″)
Washington County group, 700–800 feet	XVI	Jollytown (2′ 0″—3′ 0″), Washington (*A*) (4′ 0″—5′ 0″) Washington (5′ 0″—8′ 0″), Little Washington (0′ 6″—0′ 10″) Waynesburg (*B*) (1′ 0″—2′ 0″), Waynesburg (*A*) (3′ 0″—4′ 0″)
Monongahela River series, 350–450 feet	XV	Waynesburg (4′ 0″—10′ 0″), Uniontown (3′ 0″), Sewickley (5′ 0″—6′ 0″) Redstone (3′ 0″—5′ 0″), Pittsburg (4′ 8″—19′ 0″)
Pittsburg or Lower Barren measures 550–650 feet	XIV	Little Pittsburg (1′ 0″—2′ 0″), Elk Lick or Barton (2′ 0″—4′ 0″) Platt or Crinoidal (1′ 0″—1′ 8″), Bakerstown or Price (3′ 0″—4′ 0″) Masontown or Brush Creek (0′ 6″—4′ 0″), Mahoning (1′ 0″—3′ 0″)
Alleghany River or Lower Productive series, 250–300 feet	XIII	Upper Freeport (*E*) (1′ 0″—6′ 0″), Middle Freeport (*D′*) (2′ 0″)* Lower Freeport (*D*) (4′ 0″—7′ 0″), Upper Kittanning (*C′*) (0′ 6″—3′ 0″) Middle Kittanning (*C*) (2′ 0″—4′ 0″), Lower Kittanning (*B*) (3′ 0″—4′ 0″) Clarion (*A′*) (3′ 0″—5′ 0″), Brookville (*A*) (4′ 0″—5′ 0″)
Pottsville conglomerate series, Millstone grit, 200–300 feet	XII	Mercer Upper (0′ 4″—2′ 6″), Mercer Lower (0′ 8″—3′ 1″) Quakertown (1′ 0″—2′ 0″), Sharon (1′ 6″—4′ 0″)

*Local. Not a regular member of the series.

93. Table II shows a general section of the coal-bearing strata in Pennsylvania, which, in part, agrees with that in the adjoining states. There are other seams of occasional local importance, but of limited extent, that are not shown in the table.

A number of these seams have been identified and correlated in Ohio, West Virginia, and Maryland, but in each of these states are many local seams that cannot be correlated or connected with any in Pennsylvania. Attempts have been made at various times to correlate coal seams in the middle and western coal fields with those in Pennsylvania, but without success. Nor is it possible to correlate with any degree of accuracy the seams in the anthracite coal fields with those in the bituminous, or even in the separate fields of the anthracite region.

94. The alternations of limestones and other strata containing marine fossils with coal strata composed of land and fresh-water plants indicate numerous inroads of the sea, probably caused by depressions of the coastal areas. The character of the rocks shows that at times there were large land and swamp areas, succeeded by deeper water and sand and mud deposits, and at times clear water in which life was abundant and limestones were formed.

In the Rocky Mountain regions of the Western United States, the Carboniferous rocks, wherever they occur, consist of limestones and sandstones and contain no coal seams.

The fossils of the Carboniferous sediments are very abundant. The trilobites that have been abundant during the preceding periods now rapidly decrease and disappear. A few species are found in the Carboniferous, but none after it. The brachiopods are abundant, but are of a different type from those in the Devonian. The mollusks are abundant and varied in kind. The crinoids are more abundant in number and variety in the Lower Carboniferous than in any previous period. The blastoids, small bud-like forms similar in many ways to the crinoids [see Fig. 48 (*a*), (*b*), and (*c*)], here reach their highest development and disappear. The bryozoans are

represented by the unique screw-shaped form [see (*g*), Fig. 48]. The fossil spiders, scorpions, and insects are abundant for the first time in the rocks of the Carboniferous period. Fishes are abundant, and amphibian animals that lived both on land and in the water occur in considerable numbers. In Fig. 48 are shown some of the fossils of the Lower Carboniferous period. Reptiles make their first appearance in the Permian, at the close of the Carboniferous period.

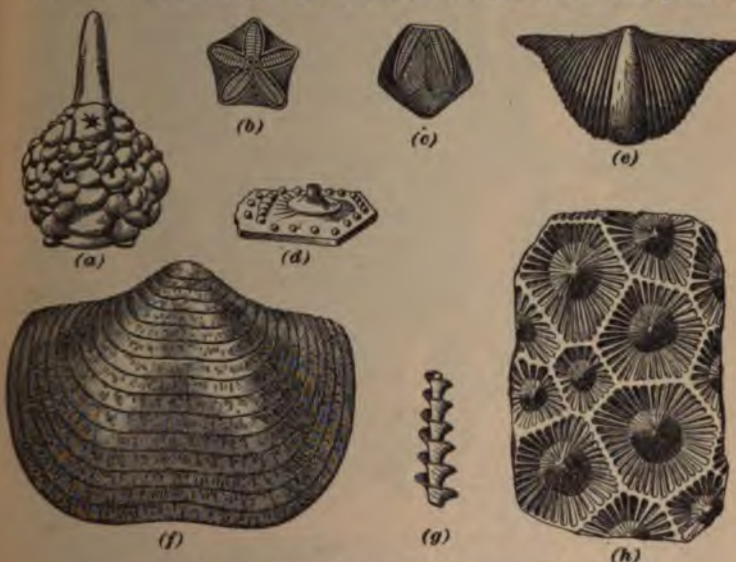


FIG. 48. LOWER CARBONIFEROUS FOSSILS

(*a*), (*b*), and (*c*), Echinoderms (Blastoids); (*d*), Base of spine from Echinoderm; (*e*), Brachiopod (Spirifer); (*f*), Brachiopod (Pirductur); (*g*), Bryozoan (Archimeder northeni); (*h*), Coral

The plant fossils of the coal period possess a high degree of importance. The plants that appear in considerable numbers in the Devonian period continue to increase through the Lower Carboniferous, and reach such a high stage of development in the coal measures as to supply the material necessary to form the many coal seams of this period, besides the many plants preserved in fossil form in the other rocks. These plants, with few exceptions, were flowerless, and comprised: (1) ferns, which were very abundant; (2) lepidodendrids,

which grew quite large, sometimes 50 or 60 feet in height; (3) sigillaria, which also grew to large size; (4) stigmaria, root-like stems; (5) calamites, or tree rushes, which were sometimes 20 feet or more in height. The flowers of the few flowering plants were simple and inconspicuous.

FIG. 49. CARBONIFEROUS FOSSILS

(a), Lepidostrobus; (b) and (c), Sigillaria; (d), Lepidodendron modulatum; (e), Lepidodendron diplotegioides; (f), Sigillaria greseri; (g), Lepidodendron rigens; (h), Sigillaria levigata; (i), Sigillaria reticulata; (j), Lepidophloios acadianus, fruit; (k), Calamite, restored; (l), Lepidodendron corrugatum, branch and fruit; (m), Sigillaria obovata; (n), Asterophyllites foliosus; (o), Lepidodendron corrugatum, branch and leaves; (p), Lepidodendron politum; (q), Calamites, lower end of stem; (r), Leaf of sigillaria elegans; (s), Calamites canneformis, lower end of stem

Figs. 49 and 50 show a number of the more common fossils of this period, some of which may be found in the shales and clays of almost every coal mine, and sometimes they occur in the coal itself. The fern leaves are more frequently found

in the black shales overlying the coal; and the stigmaria,

FIG. 50. CARBONIFEROUS FOSSILS

1. Welwitschia; 2, A conifer leaf of half natural size of living congener; 3, Alethopteris lonchitica; 4, Neuropteris flexuosa; 5, Callipteris sullivanti; 6, Pecopteris strongii, showing fructification, (a) a leaflet; 7, Alethopteris massilonis; 8, Odontopteris wortheni; 9, Alethopteris (7), enlarged; 10, Phyllocladus, a branch; 11, Salisburia, a branch; 12, Section of fruit of salisburia; 13, 14, 15, 19, 20, 22, 25, and 26, Cardiocarpon; 23 and 24, Rhabdocarpon; 18, 27, and 29, Trigonocarpon; 16, Neuropteris flexuosa; 17, Hymenophyllites alatus; 21, Pecopteris strongii; 28, Neuropteris hirsuta

which are thought to be root stems of sigillaria, and possibly some of the other forms, occur in the clays underlying the coal.

95. Climate of the Carboniferous.—The climate of the coal period was more uniform and probably warmer and more moist than our present climate. Plant forms such as thrive best in the tropics and temperate latitudes were abundant. But since these plants occur in this period at all latitudes, even in the arctic regions, it is thought the climate at that time was warm and uniform in all these zones. This is further indicated by the occurrence of corals on the island of Spitzbergen, in the arctic region, as such corals are now found only below latitude 30° and where the mean annual temperature does not fall below 60°. Also, the abundance of plants that flourish only on islands or seashores would indicate for this period a moist climate, which would be the natural result of great water areas, as indicated by the coal swamps, and a warm temperature.

96. The Jura-Trias Period.—At the close of the Carboniferous period, the conditions favorable for the accumulation of large quantities of vegetable matter in the form of coal beds were greatly lessened, and in the Triassic and Jurassic periods following, extensive beds of sandstone, conglomerate, and shale were formed; but the prevailing red color of these rocks in many localities, due to the unreduced red oxide of iron, indicates a condition unfavorable for the preservation of organic matter, which, if present, would reduce the red oxide and thus change the color of the rocks.

In the Eastern United States, several small coal basins were formed, the largest and most important of which is the Richmond basin in Virginia. There are several smaller deposits in North Carolina and in Pennsylvania. In the Western United States there were extensive inland lakes.

The plant life of this period consisted, in part, of the same types as in the Carboniferous. The lepidodendrids and sigillaria disappeared, and new groups (cycads) that were scarcely noticeable in the Carboniferous, now became quite prominent.

There were quite marked changes in the animal life, as during this period the great reptiles reached their greatest development, and included some of the largest animals that ever existed on the earth. In the fresh-water

the lakes of that period, on the western plains of Wyoming and Colorado, are the most extensive deposits of these huge reptiles anywhere known. Some fragmentary remains and many tracks of reptiles have been found in the Connecticut Valley and in Eastern Pennsylvania. Remains of winged reptiles and the first fossil birds have been found in the Jurassic rocks in European localities.

97. Cretaceous Period.—As the Carboniferous, the closing period of the Paleozoic era, was the great coal-forming period in the Eastern and Central United States, so the Cretaceous, the closing period of the Mesozoic era, was the coal-forming period of the western region. Like the Carboniferous, it is divided into two parts, the Lower and Upper Cretaceous, and similarly, also, the upper division is the coal-bearing period in each, almost no coal occurring in the lower division. These two periods, the Carboniferous and the Cretaceous, contain nearly all the workable coal seams.

In the Eastern United States, the Cretaceous deposits consist of beds of clay, sand, greensand, and marl, forming a strip along the Atlantic and Gulf border just east and south of the upland hilly country of the Precambrian rocks. In the western plains, the Rocky Mountain and Pacific Coast regions, the deposits consist of extensive beds of shales, sandstone, marls, limestone, chalk, and coal. The most extensive chalk deposits lie in Kansas, Arkansas, and Texas, while coal occurs in nearly all the western states and in portions of Alaska.

The plant life of the Cretaceous period indicates many changes since the Carboniferous period, as the plants have lost many of the more ancient features and become more like those of the present time. Associated with the Cretaceous coal beds occur fossil leaves similar to those of the trees of the present day, such as the sassafras, willow, oak, beech, palms, etc., none of which occur in the Carboniferous rocks, but are quite abundant in the Cretaceous. Some of the fossils of the Cretaceous are shown in Fig. 51.

The changes in the animal forms are scarcely less marked; ire a bony skeleton and more nearly resemble

the fishes of today. The earlier fishes had a cartilaginous skeleton, and the vertebræ extended to the end of the tail, a quite different arrangement from that of the modern fishes. The shells were more like those of today than those of the earlier Paleozoic time. The microscopic

FIG. 51. CRETACEOUS FOSSILS

A, Restoration of Ichthyornis victor (after Marsh); *B*, Hadrosaurus (restored by Hawkins); *C*, Belemnites impressus (after Gabb); *D*, Salix proteafolia; *E*, Liquidambar integrifolium; *F*, Protophyllum quadratum; *G*, Laurus nebrascensis; *H*, Sassafras araliopsis; *I*, Fagus polyclada

lime-bearing shells, such as occur in the ooze of the deep seas today, were abundant, and are supposed to have formed a great part of the extensive chalk beds of England, France, and the United States. The birds lost many of the reptilian features, and became more like our present-day birds, and

the mammals became more abundant. The giant reptiles of the preceding period became extinct before the close of the Cretaceous period.

Many of the coals of the Cretaceous period are not inferior in quality or quantity to those of the Carboniferous period, though there is possibly a larger percentage of lignite and low-grade coals than would be found among the Carboniferous coals. The deposits extend over almost as large an area, and many of the beds are just as thick as those of the Carboniferous age.

98. Following is a section of the Cretaceous rocks in the middle west. The names of the groups and the character of the sediments are different in the Gulf States and Atlantic coast region.

Upper Cretaceous	Livingstone-Denver beds
	Laramie—Fresh and brackish water deposit, extensive coal beds, and shales
	Fox Hills—Sandstone, some coal
	Fort Pierre—Shales and limestones
	Niobrara—Chalk, marls, and limestone
	Benton—Shales and limestones
	Dakota—Sandstone, forming the hogbacks east of the Rocky Mountains
Lower Cretaceous—Como group—Thought by some to be Jurassic	

99. Cenozoic Time.—The Cenozoic time, including the Tertiary and the Quaternary, or Pleistocene, extends from the Cretaceous period to the present. It includes more or less extensive deposits of sediment along the Atlantic and Gulf coasts, and many fresh-water deposits of the western interior region and the west coast. Plant and animal life became more and more like that of the present. Mammals became more abundant, and man made his appearance. The forests and lower vegetation gradually merged into those of the present. Extensive accumulations of vegetable matter took place, forming lignites in the Tertiary and peat beds in the Quaternary periods. The lignites reach their greatest extent in the Eocene, or early Tertiary, period, and are most abundant in the Gulf States and the Pacific Coast regions.

COAL FIELDS OF THE UNITED STA

NOTE.—The map of the coal fields of the United States accon ing this Section is adapted from the most recent map issued United States Geological Survey and republished through the co of the Director of the Geological Survey.

The principal coal fields are indicated by numbers, and the by which they are commonly known are as follows:

Northern Appalachian.—(1) Clearfield, (2) Broadtop or Hu don, (3) Connellsville, (4) Pittsburg, (5) Massillon, (6) Hocking (7) Fairmont, (8) Georges Creek and Piedmont, (9) Kanawh New River, (10) Pocahontas.

Southern Appalachian.—(11) Jellico, (12) Chattanooga, (1 mingham.

Northern Interior.—(20) Michigan.

Eastern Interior.—(30) Indiana Block Coal, (31) Illinois-I Bituminous, (32) Western Kentucky.

Northern Rocky Mountain.—(50) Lewis & Clarke Field Great Falls Field, (52) Judith Basin Field, (54) Clark Fork (55) Big Horn Basin Field, (56) Rocky Fork Field, (57) Yello Field, (58) Trail Creek Field, (59) Ruby Valley Field, (60) We latin Field, (61) Cinnabar Field, (62) Wind River Field, (63) S Field, (64) Hams Fork Field, (65) Rock Springs Field, (66) R Field, (67) Hanna Field, (68) Carbon Field, (69) Henry's Forl

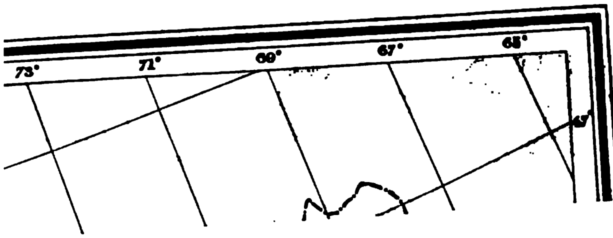
Southern Rocky Mountain.—(70) Yampa Field, (71) North Field, (72) South Platte Field, (73) Grand River Field, (74) W Field, (75) Henry Mountains Field, (76) La Plata Field, (77) Taylor Field, (78) Gallup Field, (79) Raton Field, (80) Tejon (81) Los Cerillos Field, (82) Jarillosa Field, (83) Carthage Fie

Pacific Coast.—(100) Whatcom, (101) Skagit, (102) New (103) Franklin, (104) Wilkeson-Carbonado, (105) Roslyn, (106 Bay, (107) Mount Diablo, (108) Corral Hollow, (109) Ione Elsinore.

The names here given are, in general, the trade or comr names and in some cases differ slightly from the names appl geologists. In the following pages, the numbers in parenth the text refer to the numbers on the map.

ANTHRACITE

100. Pennsylvania.—The anthracite field of Pe vania lies in the central portion of the eastern part state, and is one of the most productive mineral de in the world. The total area in which the coal is fo 485 square miles.



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The strata are sharply folded, and the coal lies in separate synclinal basins. The coal measures have been entirely eroded from the intervening anticlinals, and the durable Pottsville conglomerate forms the outer rim or edge of each of the basins.

The area of the field is so small and the mines and borings so numerous that the number and thickness of the seams in different parts of the different basins are pretty well known. The main features of all the principal seams are shown on the detailed maps and reports of the Second Geological Survey of Pennsylvania, and only the merest outline can be given here.

The thickness of the measures differs considerably in different localities. The greatest thickness is found in the southern part, where it is more than 2,500 feet. The deepest portion of the western middle field is about 1,200 feet; the deepest portion of the eastern middle field is about 500 feet, and of the northern field about 2,200 feet. These figures represent the maximum thickness in the middle portions of the basins, from which there is a thinning out to zero on the rim of the basin.

There is variation in the number and thickness of the separate seams in the different basins, and while there are nearly as many seams represented as in the bituminous measures of the central and western parts of Pennsylvania, it is not possible to correlate the separate seams in the two areas, nor is it possible to correlate all the seams in the separate basins in the anthracite region.

The Pottsville conglomerate that forms the base of the coal measures in the anthracite region was probably at one time connected with the conglomerate-sandstone bed at the base of the bituminous coal measures; but in the folding of the Alleghany Mountains, and the subsequent erosion, all the coal measures were swept away from the intervening area, thus separating the anthracite area from the bituminous. The conglomerate of the anthracite region is much coarser grained and contains larger pebbles than that in the western part of the state, and it also contains more coal, several valuable seams of anthracite occurring in the conglomerate.

101. The coal measures overlying the conglomerate are not divided into four divisions, as in the bituminous area. They consist of beds of sandstone, conglomerate, shale, fireclay, limestone, and coal. In comparison with the bituminous coal measures, the anthracite measures have more conglomerate, less fireclay, less limestone, and all the rocks are more metamorphosed, and, hence, harder. There are a few thin layers of impure limestone in the northern part of the anthracite field, but none in the middle and southern parts.

The measures have coal beds distributed throughout their whole extent, the beds varying in thickness from a few inches up to 50 to 60 feet. In general, it may be said that the lower 300 to 500 feet of the coal measures up to the top of the Mammoth bed contain the thicker deposits. These coal beds are separated by intervals varying from a few feet to several hundred feet, but a barren interval of over 200 feet is rare. The rocks intervening between the coal beds may be classified as follows: (1) brown or gray sandstones, varying in texture from soft and shaly to coarse and hard, and merging into fine conglomerates, which, in some instances, are so coarse as to be mistaken for the Pottsville conglomerate; (2) shales of various degrees of hardness and varying in color; (3) black, carbonaceous slate or shale; and (4) fireclays, frequently, but not always, underlying the coal, and also frequently found apart from the coal beds. The intervals between the same coal beds vary greatly in different basins, and even in different parts of the same basin.

Many of the seams are thicker than any in the bituminous areas, the Mammoth seam having a thickness of 50 to 60 feet over considerable areas. In one place, near Mauch Chunk, it reaches the surprising thickness of 114.2 feet, but this is probably due to a sharp fold in which the bed is doubled on itself.

In all the basins, the strata are not only sharply folded, but contain many faults as well, which are mostly reverse or thrust faults.

There is considerable variety in the chemical and physical properties of the coals from different parts of the region.

While all are hard anthracite, some contain much more volatile matter than others; some have a higher percentage of ash; some burn to a red ash, due to the higher percentage of iron, and others to a white ash. A general average of analyses from many car-load lots gives the following composition for the average commercial anthracite: fixed carbon, 84 per cent.; volatile hydrocarbons, 3.8 per cent.; ash, 8.4 per cent.; sulphur, .5 per cent.; water, 3.3 per cent.

102. **Rhode Island and Massachusetts.**—Strata of the Carboniferous age containing coal seams occur north of Newport, Rhode Island, and in Southern Massachusetts. The coal is highly metamorphosed, and resembles graphite so much that it is sometimes classed as graphitic coal. The associated rocks are all highly metamorphosed; the conglomerates have been changed to a gneiss, and the shales to slates. The coals still contain some hydrocarbons, but do not kindle or burn readily, and attempts to use them for fuel have not met with success. They have been mixed with petroleum, asphalt, and other hydrocarbon compounds, but none of the ventures has proved profitable. Some of it is now used for foundry facings, fireproof paint, and crucibles. Small quantities of anthracite are mined in Virginia and in Nova Scotia.

103. **Anthracite in the Western States.**—Anthracite occurs in several of the western states, where it has been formed from the bituminous by intersecting dikes of igneous rock, or by proximity to sheets, laccolites, or other intruded masses of igneous material. The most productive anthracite mines at present in the West are in Colorado and New Mexico. At Crested Butte, Colorado, both anthracite and coking bituminous coal occur. The anthracite is the best known of any of the western ones. It occurs in two seams, from 4 to 7 feet thick, both of which are worked. An anthracite breaker with 300 tons daily capacity has been in operation for several years. Anthracite in small quantities occurs in the Yampa field in the northwestern part of Colorado.

Another producing anthracite region is the Los Cerrillos, in the Santa Fé field, in New Mexico, which produced at the rate of 10,000 tons a year as long ago as 1893. The field lies in the Cerrillos Mountains, some 50 miles north of Albuquerque. It produces both bituminous coal and anthracite, and contains seventeen coal seams, of which four are more than 4 feet thick. The anthracite seam is 3½ to 4 feet, with a sandstone roof. About 50 feet above the anthracite is a seam of bituminous coal, but between the two, near the top of the anthracite, is an intrusive sheet of eruptive rock that is probably the cause of the anthracite.

Anthracite is mined in considerable quantities in Alberta, Canada, Anthracite Station on the Canadian Pacific Railway being one of the most important producing points. The coal occurs in several seams 4 to 5 feet thick, and is Lower Cretaceous in age.

BITUMINOUS COAL

104. The bituminous coals of the United States may be conveniently divided into those of the Carboniferous age and those that were formed afterwards. The Carboniferous coals include all those in the Eastern and Middle United States, except a limited area of Triassic coal in Virginia and North Carolina.

The Carboniferous era is divided into five areas; namely: (1) the Appalachian field, which is sometimes subdivided into the Northern Appalachian and the Southern Appalachian, and extends along the plateau on the west side of the Alleghany Mountains from Northern Pennsylvania and Ohio through West Virginia, Kentucky, Maryland, Virginia, Tennessee, into Alabama, and a small area in Northwestern Georgia, covering a total of about 70,800 square miles, of which 75 per cent. contains workable coal; (2) the northern interior, or Michigan, area, in the southern peninsula of Michigan, which comprises about 11,000 square miles; (3) the eastern interior area, which includes Western Indiana, Western Kentucky, and a large part of Illinois, and covers about 58,000 square

miles; (4) the western interior and southwestern areas in Iowa, Missouri, Kansas, Arkansas, Indian Territory, and Texas, which comprise about 94,000 square miles; and (5) the Acadian area, 2,200 square miles, in Nova Scotia and New Brunswick.

APPALACHIAN COAL FIELD

105. Pennsylvania.—Pennsylvania is the greatest coal-producing state in the Union, both of anthracite and bituminous. The bituminous area covers a large part of the state west of the eastern escarpment of the Alleghany plateau, except a narrow strip in the north and northwest part of the state. The main field is divided by low anticlinals into six synclinal basins that have a general northeast-southwest trend parallel with the mountain ridges. There are also two outlying basins: (*a*) the northern extension of the Cumberland basin of Maryland and West Virginia (8), and (*b*) the Broad Top coal field in Huntingdon County (2). These synclinal basins pitch deeper toward the south and thin out at the north end. Hence, we find the lowest and oldest coal beds on the north and east sides of the area, and the newest coal seams in the southwest portion of the state, nearer the central part of the great basin.

The Lower Carboniferous strata in Western and Central Pennsylvania are divided into the Pocono sandstone and the Mauch Chunk red shale, as in Eastern Pennsylvania. In the western part of the state we find these rocks becoming more calcareous, merging into a silicious limestone.

At the base of the coal measures, as in the anthracite field, lies the Pottsville conglomerate, and overlying the conglomerate is the Lower Productive, or Alleghany River, series, which outcrops in large areas along the east and north sides of the bituminous area. This series contains the following coal seams in order, beginning at the base: Brookville, or A seam; Clarion, or A′; Lower Kittanning, B; Middle Kittanning, C; Upper Kittanning, C′; Lower Freeport, D; and Upper Freeport, E. They are all named from well-known localities in Pennsylvania. Some of these seams extend

quite widely over the area; others are more local in occurrence and are found only in limited areas; while there are a few other productive seams not correlated with any of the above. These seams are separated by beds of fireclay shale, sandstone, limestone, and iron ore, which vary in thickness in different localities.

106. The second division of the coal measures in Pennsylvania is known as the Lower Barren, or Pittsburg, series, and overlies the Lower Productive measures, outcropping south and west of them through central Western Pennsylvania, typical exposures occurring at the base of the hills around Pittsburg. This division consists of a series of gray, buff, black, and red shales, containing some sandstone and several small coal seams locally productive.

The Upper Productive, or Monongahela, series overlies the Lower Barren and covers a large area over the southwestern part of the state, south of Pittsburg. Interstratified with beds of shale, sandstone, and limestone are several productive coal seams, of which by far the most important is the famous Pittsburg seam, one of the most productive coal seams in the world. It underlies an area of many thousands of square miles in Southwestern Pennsylvania, Ohio, Maryland, and West Virginia, and extends over wide areas with great uniformity of structure, as indicated in the sections in Fig. 37.

It outcrops near the tops of the hills at Pittsburg at its northern limit, from which it dips gently to the south and west, so that it lies deeply buried in the southwest corner of the state. The dip is not uniform, as it follows the broad gentle folds that affect all the strata of Western Pennsylvania. The Monongahela River cuts across these folds, and the Pittsburg coal seam is exposed along its bluffs as a great black band, or ribbon, in some places near the top of the hill, from which it descends in broad sweeps to near or sometimes below the level of the river, to rise again in another fold. It is on this exposed edge that numerous mine openings have been made. The coal is carried out on tipples to the

bank of the river, where it is dumped into barges, and floated down to Pittsburg and points along the Ohio and Mississippi Rivers.

The Pittsburg coal, besides being a good steam coal, is an excellent gas coal and one of the best coking coals in the United States, being the source of the famous Connellsville coke.

There are other coal seams, the Redstone, the Sewickly, and the Uniontown, that lie higher in the Upper Productive series, but none of equal importance with the Pittsburg seam. The Upper Barren measures, which form the surface rocks in the southwestern corner of Pennsylvania and extend into the adjoining states, contain several productive coal seams, the most important of which is probably the Washington seam, near the base of the series. The strata of the Upper Barren measures are thought by some to be of Permian age, by others Triassic.

107. Ohio.—The coal measures cover the eastern third of the state, and many of the seams are continuations of those already mentioned in Pennsylvania. Thus, the Brookville, Clarion, Lower and Middle Kittanning, and Upper and Lower Freeport coals of the Lower Productive series, and the Pittsburg and Sewickly beds of the Upper Productive series of Pennsylvania, have been recognized in Ohio. Besides these, there are seams not correlated with any in Pennsylvania, several of which occur in the Pottsville conglomerate at the base of the coal measures. The Ohio coal seams have a general average thickness of from 4 to 4½ feet. The coals, as a rule, are not good coking coals. The strata have a gentle dip southeastwards toward the Pennsylvania-West Virginia coal areas, and the seams are regular and but little disturbed by folding and faulting.

108. West Virginia is almost entirely covered with coal-bearing strata, forty-eight out of fifty-six counties containing coal. The West Virginia coals are all bituminous, but there are many varieties. Many of them are excellent coking coals, and West Virginia promises to equal Pennsylvania as a

coke-producing state. Good gas coals and cannel coals ai mined at different points. Among the most important co areas of the state are the Elk Garden and Upper Potom fields, which form the southern extension of what has bee called the Potomac basin. This basin includes the Weller burg area in Pennsylvania and the Cumberland and Georg Creek fields in Maryland (8), the latter extending in West Virginia.

The Elk Garden district extends from near Piedmor West Virginia, to Stony River, a distance of about 20 mile The field has the shape of a wedge with the narrow end the north. It lies on both sides of the Potomac River, ai includes both the Upper and Lower Productive coal mea ures and also many of the well-known seams of both serie such as the Pittsburg (the big vein), 13 to 16 feet thick, t Freeport (4-foot vein), and Kittanning (6-foot vein). one place the 7-foot vein above the Pittsburg is mine

The Upper Potomac field extends from the Elk Gard field through Grant and Tucker Counties, West Virginia, t principal mines being at Thomas, Davis, and Douglas. T most productive seams in this area are the Upper Freep (Thomas) and Lower Kittanning (Davis), and a small area the Pittsburg seam occurs in the Summit of Fairfax Knc This is a large and important coal field. It has been es mated that there is an area of not less than 250 square mil containing 2,000,000,000 tons or more of coal. The coal a good coking, steam, and smithing coal. It has a colum structure, breaks easily by hand, and runs low in sulph The coke is bright, silvery, porous, and hard, and has excellent reputation for foundry, blast furnace, and dom tic use.

The Roaring Creek coal field forms a part of the m Appalachian field, and is not an outlier, or isolated coal fie like the ones just mentioned. It lies in the northern part Randolph County and the southern part of Barbour Coun The Tygarts River flows diagonally through the basin, cutt the eastern rim near Elkins, thus opening an easy ga way to the field. Both the Upper Freeport and the Lov

Kittanning coals occur, but the former is by far the more important. This seam, with the included coal and bone, runs from 16 to 30 feet. A section at the Custer mine shows coal and bone 7 inches, coal 18 inches, slate 1 inch, coal 14 inches, slate 7 inches, and coal 12 inches. At Wilson's mine, on Roaring Creek, a section shows slaty coal 18 inches, dark shale 2 inches, coal upper bench 32 inches, slate and bony coal 15 inches, breast coal 37 inches, gray slate 6 inches, mining ply coal 20 inches, clay and shale 4 inches, bottoms, slaty coal 1 inch. The merchantable coal varies in different mines from 4 feet 6 inches to 8 feet 5 inches.

The Loup Creek coal field lies entirely in Fayette County, and is a portion of the greater New River field. The field is remarkable for its regularity and freedom from faults and distortions. The strata have a very regular dip to the southeast of about 3 feet in 100, and the principal seam averages about 5½ feet thick.

The fields just mentioned are the newer fields in the state, and in addition to them, the coal fields of West Virginia may be divided, commercially, into the Fairmont field, tributary to the Baltimore & Ohio Railroad, the Kanawha, New River field, tributary to the Chesapeake & Ohio Railroad, and the Pocahontas field, tributary to the Norfolk & Western Railroad.

The Fairmont or Upper Monongahela coal field is continuous with the coal areas of Western Pennsylvania and Eastern Ohio. Fairmont is the center of mining operations, which extend from Morgantown on the north to Clarksburg on the south. The Kanawha field extends from Charleston on the west a distance of 25 miles; toward the southeast there is then a barren area of about 5 miles, beyond which the field is known as the New River. The Pocahontas or Flat Top field is in the extreme southern part of the state and takes its name from the town Pocahontas just across the Virginia state line and the Flat Top mountains.

109. **Maryland.**—The coal area in Maryland, known as the Georges Creek district, is small but important. It

contains the famous Cumberland basin (8) that extends northwards into Pennsylvania and southwards into West Virginia. The Lower Productive coal measures occur, but by far the most important is the Pittsburg seam, known locally as the *14-foot seam*, which is here semibituminous in character, and is a steam coal that is used extensively on the ocean vessels.

110. Virginia.—The Carboniferous strata in Virginia lie in the southwestern part of the state, and contain, in the Flat Top field, some of the best coking and steam coals in the Appalachian field. It goes to the market as Pocahontas coal, and is used extensively by transatlantic steamers. The Big Stone Gap coal field, south of the Flat Top field, is an important producer, and farther east in Wythe, Pulaski, and Montgomery Counties is geologically the oldest coal field in the United States. It is now nearly abandoned, as the coals, which belong to the Lower Carboniferous period, are inferior in quality to those farther west.

111. Eastern Kentucky.—About 11,180 square miles of Eastern Kentucky are underlain by bituminous coals of different grades. The seams extend northwards into West Virginia and southwards into Tennessee, and in the southeastern part there are the good coking coals. Excellent cannel coals are likewise mined in Eastern Kentucky.

112. Tennessee.—The coal measures in Tennessee are divided into three series, of which the upper series is the thickest (3,000 feet), although the smallest in area. It contains twenty seams of coal, of which eleven are workable. The coals of Tennessee are bituminous and coking.

113. Alabama.—The coal territory of Alabama is separated into four fields, which, with the area of workable coal, are as follows: Warrior, 2,625 square miles; Coosa, 345 square miles; Cahaba, 270 square miles; Blount, 100 square miles. The total thickness of the coal measures is 5,000 feet, and more than fifty seams of coal are represented. The Warrior field is not only the largest, but the most productive, the largest mines lying west and

southwest of Birmingham. A large part of the coal is coked for use in the many blast furnaces in the Birmingham district.

NORTHERN INTERIOR COAL FIELD

114. The northern interior, or Michigan, coal field, occupies the central portion of the southern peninsula of Michigan, having an area of 11,000 square miles. The area has been covered by the glacier and the surface considerably modified thereby. The thickness of the coal measures in the center of the basin is 600 to 700 feet.

Recent discoveries indicate that the Michigan coal fields are equivalent to the Pottsville formation. The Verne coals near the top of the measures seem to correspond with the Mercer coals of Ohio. Usually, just above the coal is a black slate, and sometimes the coal passes into an impure cannel or bone coal, this low grade cannel being characteristic of the Michigan field.

It was formerly supposed that the field contained but one workable bed, but this has been shown not to be the case, and seven coal horizons are now known; of these, three are much more important than the others. The output has increased quite rapidly during the past few years, reaching a total of nearly 900,000 tons in 1900.

EASTERN INTERIOR COAL FIELD

115. The eastern interior coal field covers 46,000 square miles in Central and Southern Illinois, Southwestern Indiana, and Northwestern Kentucky. It lies in an elliptical basin, the center of which is in Illinois.

116. Illinois.—Next to Pennsylvania, Illinois is the largest coal-producing state in the Union. The coal measures occupy all the central and southern portions of the state, 600 to 800 feet thick on the north, and increasing to 1,200 to 1,400 feet on the south. Sixteen coal seams occur, but not all are productive. The most productive portion is St. Clair County, just east of St. Louis, and thence northeastwards

toward Chicago. It is largely a level prairie reg the coal is generally mined through shafts 50 to deep, but in some places the seam lies so near th that the overburden is removed and the coal qua: from the surface. The coal is bituminous and is nc coking coal.

117. Indiana.—In Indiana fourteen or mor are known, including the celebrated Brazil block c The coal measures of Indiana have been divided groups, with the Mansfield sandstone, which prob responds to the Pottsville conglomerate of Penn at the base, and the Merom sandstone, possibly of age, at the top. There are a number of small fa minor folds, but the strata are in general nearly ho with a slight dip to the south and west.

118. Western Kentucky.—The southern en synclinal basin of the eastern interior coal field, about 4,500 square miles, lies in Kentucky, in tl River basin (32). The coals are good fuel and ste and some are coking coals; while in the northeaster of the area lies the celebrated Breckenridge canne which the workable coal is confined mainly to tv the No. 9 is the more important. This bed has an thickness of 5 feet, and lies at a depth of about 200

WESTERN INTERIOR AND SOUTHWESTERN COA

119. The western interior and southwestern coal field lies in the Mississippi valley, on the v of the Mississippi River, extending from Iowa on t through Missouri, Kansas, Indian Territory, and into Texas, covering an area of 98,500 square mil twice as large as the eastern central field. The ea western interior fields structurally form a single the Mississippi, cutting across, has separated it into

120. Iowa.—In Iowa, at the northern end of field, the measures are divided into the lower De

stage, consisting of sandstones, shales, clays, and coal, and the upper Missouri stage, consisting largely of limestones. There are twelve or more coal seams, but they are not so widespread as in the eastern fields. Many of them are quite local in extent, and they cannot be so closely correlated over wide areas. The average thickness of the seams mined is from 4 to 5 feet. There are many irregularities, such as horsebacks, rolls, pinches, swells, and small faults. The coals are bituminous, non-coking, but valuable fuel and steam coals.

121. Missouri.—In Missouri, the coal measures cover the northwest half of the state, forming a rolling plateau bordering the Ozark uplift. The strata have a thickness of 1,900 feet, and are divided into the Upper or Barren, Middle, and Lower divisions, with most of the coal in the Lower division. The seams range in thickness from a few inches to 5 feet. Most of the coals are sulphurous. As in Iowa, the seams are cut by many stream channels, some of which are preglacial.

122. Kansas.—Eastern Kansas contains part of the Missouri-Iowa coal field, which covers a strip about four counties deep along the east side of the state, the two most productive counties being Cherokee and Crawford in the extreme southeast. There are twenty-two seams, but less than half of them are productive. The Cherokee seam, from 3 to 4 feet thick, is the largest, and furnishes a good fuel and coking coal. Some cannel coal is produced.

123. Indian Territory and Arkansas.—This coal field forms an east and west synclinal basin, beginning about 75 miles west of Little Rock and extending west and a little south nearly through the Indian Territory. Near the eastern end of the field the coal is semianthracite in character. The Arkansas area is divided into the western, or upper, division and the eastern, or lower, division, and geographically into the Onita, Philpot, Coal Hill, and Sebastian County districts. Anthracite, semianthracite, and bituminous coals occur.

124. Texas.—In Texas, there are two coal fields of Carboniferous age, the southern extension of the western interior field. These lie in the Brazos and Colorado River valleys. The coals are, in general, a lower grade, and in thinner seams, than some of the areas farther north, but they have commercial value because of their remoteness from other mines.

Besides the Carboniferous coals in Texas, there are lignites in the eastern and southeastern parts of the state that have some commercial importance.

COALS OF TRIASSIC AGE

125. Along the Atlantic seaboard, east of the Appalachian Mountains, there are a number of long, narrow deposits of Triassic coal covering an area of about 1,000 square miles. The Richmond basin, probably the best known, lying southwest of Richmond, Virginia, is 30 miles long and from 4 to 10 miles broad. It rests unconformably on the old Archean rocks; in some places, the coals rest on granite. There has been considerable faulting, and many of the seams are of local occurrence and quite irregular, reaching a thickness of 25 feet in some places and thinning out in others. Trap dikes have intersected the seams in places, and the adjoining coal has been changed to a natural coke, called carbonite. In some places, the coal is of excellent quality, but is very irregular. The first systematic coal mining in the United States was carried on in this field prior to the American Revolution.

There are other areas of Triassic coal in the Dan River and Deep River sections in North Carolina, which have produced some coal.

CRETACEOUS AND TERTIARY COALS

ROCKY MOUNTAIN COAL FIELDS

126. The Cretaceous coals are to the Western United States what the Carboniferous coals are to the Eastern. The Carboniferous strata in the Rocky Mountain and Pacific Coast regions contain no coal, nor are their beds of much importance in the Triassic, Jurassic, or Lower divisions of the Cretaceous, but in the Upper Cretaceous there are seams equal in size to many of the Carboniferous seams of the East. The Rocky Mountain coal fields occupy a district along the eastern edge of the main ridge of the Rocky Mountains, extending from the Canadian boundary southwards through Montana, Wyoming, Colorado, and New Mexico for a distance of 1,000 miles. The coal-bearing formations are not continuous throughout this belt, but occupy about 60 per cent. of the distance. Another less extensive series of coal fields occurs along the western base of the Rocky Mountain range in Wyoming, Utah, Colorado, and New Mexico. Between these two main belts, in the district known as the Park region, isolated coal basins occur, in which, however, the coal is so disturbed as to be mined with difficulty. In these fields, the coal is bituminous; and in addition to them there are also extensive deposits of lignite underlying large areas east from the mountains in Wyoming, Montana, and North and South Dakota. These coal fields have not been surveyed or explored with any degree of detail, and the areas shown on the map are therefore only approximate and will undoubtedly be enlarged as further surveys are made. There are also two small areas of Cretaceous coal in Texas—the San Carlos coal field in El Paso County and the Eagle Pass field.

127. Utah.—There are two small producing coal areas in the Great Salt Lake basin of Utah; namely, the Weber River field in the north, closely related to the Green River field of Wyoming, and the San Pete field at the town of

Wales, south of Salt Lake. The seam is 5 feet thick, of Eocene age, and furnishes a coking coal. The most productive coals in Utah lie in the plateau region outside of the Great Basin, one of which is in Emery County on the eastern slope of the Wasatch Mountains. Other Utah coal fields are Ashley Creek, Coalville, Provo Cañon, and South Utah, including the Henry Mountain field. The coals belong to the Laramie division of the Cretaceous, and occur in large seams, some of which measure 11 and 15½ feet, and one, 28 feet in thickness.

128. Colorado is one of the largest coal-producing states in the west. With the exception of one or two unimportant fields, the coals are all in the Laramie group. The different areas might be grouped topographically into: The eastern foot-hills, the parks, and the western slope, of which the first is the most productive, but the others are important producers. The South Platte field lies in the north central part of the state, in the basin of the Platte River, with Boulder as the principal producing county. The coals are lignites, with a high percentage of water. The seams are of good thickness, reaching 13 feet in places. Near Cañon City, not far from the entrance to the Royal Gorge, is a small coal area. About 75 miles south of Cañon City the Raton coal field begins and extends through Huerfano and Las Animas Counties into New Mexico. It is the most productive field in the state. Trinidad, Sopris, Engleville, Gray Creek, Starkville, and El Moro are the principal coal towns, the last named being the principal coke-producing locality. The field lies in a great basin, extending from the foot-hills some 30 miles out on the plains. There are more than forty coal seams, but only four or five are workable. The most productive seam is the Trinidad, the lowest one.

Coal occurs in both the South Park and the North Park, the former containing a good coking coal.

In the northwestern part of the state lies the Yampa coal field (70), which contains several varieties of coal, lignite, coking, and anthracite.

The Grand River field, in the western part of the state, is one of the most important. Near Newcastle, there are seven seams, with a total thickness of 106 feet of coal. In several places, the coal is only ashes and clinkers on the outcrop, due to great subterranean fires. These seams include both anthracite and bituminous coals, and in some places the bituminous are coking coals. The Crested Butte locality furnishes a good anthracite as well as a good coking coal.

The La Plata field (76) lies in the southwestern part of the state. Durango is the principal town, where there are four seams. At Carbricana, they merge into one seam, 100 feet thick, but only workable in benches 3 feet to 5 feet thick.

129. New Mexico.—The largest fields are in the northern part, but only those adjacent to the railroads have been explored. Through the center of the territory there are a number of isolated tracts. Thus far, the Laramie is the only formation that has been developed. The great value of these fields is due to their nearness to Arizona, Texas, California, and Mexico, in which very little coal of value has been discovered. The principal fields are the Raton (79), La Plata (76), Mount Taylor (77), Gallup (78), Los Cerrillos (81), Tejon (80), Jarillosa (82), Carthage (83), White Oaks, Mora, and Gila.

130. Wyoming.—This is one of the richest coal-bearing states of the west, ranking next to Colorado. In Western County, on the flanks of the Black Hills, are several excellent coal seams in the Dakota group of the Cretaceous. It is a good coking coal and important to the mining interests of the Black Hills. Converse County contains mines at Glen Rock, Douglas, and Fort Fetterman. Carbon County, on the Union Pacific Railroad, contains the oldest coal mines in the state, at Carbon and Hanna. At Hanna (67), the coal reaches a thickness of 31 feet, in one place. The largest coal mines in the state are at Rock Springs (65) in Sweetwater County, where there are twelve seams, of which the lower five are worked. They vary in thickness from 4 to 12 feet. There

are large mines at Red Cañon and Almy, in Uinta Count where the main seam varies from 12 to 27 feet in thicknes

131. Montana contains a number of important co fields, some of the more important of which are name below. The Great Falls field on Cascade Creek (51), ne the Great Falls of the Missouri, where the river leaves th Little Belt Mountains, has been known and operated fc many years. The seam is about 8 feet thick, including thre clay partings. The Bozeman field lies in South Centr Montana, along the Northern Pacific Railroad. The coal a coking coal, as it is in the Cinnabar field (61), on th northern border of Yellowstone Park. The Rocky For field lies in Park County (56), 43 miles south of the Nort ern Pacific Railroad. At Red Cloud, in this field, there a nineteen coal seams, eleven of which have over 6 feet coal, 95 feet in all. The coals are bituminous, varying som what in quality. There are large areas of unexplored co land in Montana, and the output for the future will no doul be greatly increased.

In both North and South Dakota are areas of lignitic coal the extent and value of which remain to be proved. It h been found that the Cretaceous coals are more lignitic and lower grade the farther east from the Rocky Mountains the are found; hence, in the Dakotas, they are chiefly lignit and not always of high grade.

TERTIARY COAL FIELDS

132. The Tertiary formations in various parts of th United States contain a large amount of lignite coal, an in some cases along the Pacific Coast this lignite ha been converted into true coal of a fair quality by th intrusion of igneous rocks. These deposits occur chiefl in Washington, Oregon, and California, covering an area 1,000 square miles. The productive part of this area ha not been determined.

There are also large areas of Tertiary lignites in th Southern United States, and they will probably soon b

utilized for fuel. These deposits begin at the border line between Georgia and Alabama, and extend westwards through Mississippi, Arkansas, Louisiana, and Texas.

133. **Washington.**—The coal fields of Washington are the most important on the Pacific Coast portion of the United States. The productive fields are Bellingham Bay, Skagit River, Raging River, Squak Creek, Newcastle, Green River, the Wilkeson, and the Yakima and Wenatche. The fields lie largely on the east shore of Puget Sound, and Seattle and Tacoma are the principal shipping points. Some coke is made at Skagit River and at Newcastle, 18 miles east of Seattle, where there are a number of heavy seams, one 10 feet and one 24 feet thick. On Squak Creek, several coal seams are known. The Raging River area has six or seven seams. The Green River, one of the most productive fields, has several seams, the thickest of which reaches 47 feet.

134. **Oregon** has one productive coal locality, Coos Bay (106), but coal is reported from many other points. The Coos Bay coal is a lignite of Eocene age and inferior in quality to that of the Cretaceous.

135. **California.**—One of the oldest and best known productive localities in the state is Monte Diablo (107), just east of San Francisco, where there are two seams, the Clark, from 20 inches to $4\frac{1}{2}$ feet, and the Black Diamond, from 3 to $4\frac{1}{2}$ feet. The area is reported near exhaustion. Small productive areas occur in Amador and Fresno Counties.

136. **Alaska.**—The coal in Alaska occurs in the strata of the Cretaceous and Tertiary periods, at a number of widely separated localities. The first coal mines were opened at Port Graham, on the western side of the Kenai Peninsula, in 1852, but were soon abandoned. Other mines were opened later that are still in operation. Considerable prospecting has been done on Admiralty Island, and some coal mined at several points for local use, as, for instance, at Port Chatham, Kootznahoo Inlet. Coal has been mined in a small way at

Coal Bay, Unga Island, and at intervals at Chignik River in Southeastern Alaska. The discovery and exploitation of the gold field in the Yukon region caused an active search for coal in the same area, resulting in productive mines at Drew's, opposite the mouth of Hess Creek, above Circle City. The Pioneer mine, below Hess Creek, is also productive. Some coal has been produced by mines at Nulatto, still farther down the Yukon. More recently, the Cape Lisburne coal deposits in Northwestern Alaska have been worked to supply the demand at Nome and the whaling ships in the northern waters. The Cape Lisburne mines are about 200 miles from Nome, where during 1900 coal was selling at from $25 to $100 per ton; hence, the incentive for development was strong.

Many of the Alaskan coals are lignites, but some are bituminous, semibituminous, and semianthracite. Practically all the developments so far have been along the coast or the navigable rivers, the great interior portions of the country not having been explored. It would seem from the present developments that there is a sufficient supply of coal for local needs. In time, deposits of high-grade coals may be found favorably located to compete for the California markets.

COAL IN THE PHILIPPINE ISLANDS

137. There are two classes of coal in the Philippines, both of which are classed as lignite. There is a black pitchy lignite said to be Eocene in age, and a brown lignite of late Tertiary age. The latter has little value as a fuel, and is but little used, but the first is reported to be an important and valuable fuel equal to and similar in appearance to the Tertiary coals in the Western United States.

Coal seams are reported from a great many localities in the Philippines, but it is not always possible to tell from the report whether black or brown lignite is meant. In Luzon, black lignite occurs in the extreme southeastern part in the province of Albay and Tayabas. A number of coal mines have been opened in the vicinity of Antimonan, a port at the

narrowest part of the Tayabas Isthmus. Brown lignite occurs in several localities on the island.

Coal occurs in Camarines Sur, near Pasacao, on Caramuan Peninsula, and on the island of Catanduanes, which belongs to the province of Albay. All of these localities seem to lie on the edge of a coal field that stretches southwards into Sámar and is thought to contain much valuable coal. About 12 or 15 miles south of Catanduanes, on the small islands of Carraray, Batan, and Bapurapu, there is black lignitic coal resembling bituminous coal in appearance. It occurs in seams varying from 2½ to 15 feet in thickness, and as it is found close to tide water and has high calorific power, it will probably be much in demand. The analysis shows: fixed carbon, 44.455 per cent.; volatile matter, 37.463 per cent.; ash, 4.564 per cent.; and water, 13.518 per cent.

The Batan coal appears again, outcropping at Gatbó, in Sorsogón Province, where it occurs in nearly vertical seams from 12 to 26 feet in thickness. The deposit appears again in Sámar. Coal is reported from several other points along the deposit farther south. Cebú, with Albay and Sorsogón, is said to be the most important coal region of the archipelago. The existence of coal on this island has been known to the natives for a long time, and a mountain in the Naga district bears the name Uling, the native name for coal. The Spaniards learned of the coal in this locality in 1827, since which time it has been worked at intervals. The strata are much folded and faulted, and hence mining is attended with uncertainty. The coal, as shown by analyses, is of good quality and occurs in seams up to 4 feet in thickness, and one seam is said to be 8 feet thick.

Other localities in which coal is said to occur in the Philippines are Mindanao and adjacent islands, and the islands of Dinágat and Siargao. Apparently there has been but little method or system either in the exploration for coal or in the mining of it. It would seem from the reports that there is sufficient coal to encourage manufacturing on the islands, and probably a quantity sufficient for the needs of the ocean steamers.

FOREIGN COAL FIELDS

COAL FIELDS OF CANADA

138. Eastern Canada.—The principal coal fields of Eastern Canada are the Sydney and Pictou fields in Nova Scotia and Cape Breton Island. The coals are bituminous, of good quality, and occur in strata of Carboniferous age, formed during the same period as the Rhode Island, Pennsylvania, and other eastern coals.

The Sydney field lies on the coast, and, hence, has an important bearing on the coal markets of Boston and other cities on the New England seaboard. There are about a dozen workable seams, varying from 2 to 10 feet in thickness. The coal contains four basins, known as the Sydney, Lingan, Glace Bay, and Con Bay. The strata have a gentle dip toward the sea, and in some places the seams are followed out under the sea.

The Pictou field is noted for the great number of coal seams, over eighty in number. While many of these are much too thin to be commercially productive, some of them are quite large. At Stellarton, for example, the *deep seam* is 22 feet thick, and the *main seam* still thicker. At several other mines, seams 10 to 12 feet thick are worked. The three principal districts are Westville, Albion, and Vale. The strata are rather sharply folded, dipping in most places from 15° to 45°.

There are a few small Carboniferous areas in New Brunswick that produce small quantities of coal, but their total output has little commercial importance.

139. Western Canada.—The coal fields of Western Canada are much larger than those of the eastern country, and, as in the United States, the western coals are mostly

in strata of the Cretaceous period. There is a large and important coal field in the provinces of Alberta and Assiniboia, extending from the watershed of Lake Winnipeg westwards across the plains into the Selkirk range of the Rocky Mountains. As in the United States, the eastern margin of the field contains lignites that become more and more carbonized as the mountains are approached, reaching a high grade of bituminous coal, even anthracite in places. The best exposures of the coal seams are along the Bow and Belly Rivers. The former Director-General of the Canadian Geological Survey pronounced this the largest and best coal field in Canada. It is traversed by the Canadian Pacific Railway, which has been an important factor in its development. Large bituminous mines have been opened at Lethbridge, formerly Coal Banks, on a branch of the main line of the Canadian Pacific.

Anthracite is mined at Anthracite Station. The coals occur at several different horizons in the Cretaceous. The Crow's Nest Pass coal field is located in the southeast corner of British Columbia and the adjoining portions of Alberta, lying on both sides of the Rocky Mountains. There are three workable coal seams, in some places more, which vary in thickness over the area. On Coal Creek the seams are 10, 30, and 6 feet thick; near Morissey they measure 10, 36, and 6 feet. The total area of 230 square miles of coal land has been estimated to contain not less than 22½ billion tons.

Another important coal area is on Vancouver Island, on the Pacific Coast. This area bears somewhat the same relation to San Francisco and other Pacific Coast ports as the Sydney field does to the Atlantic ports. There are two basins on the island, both on the eastern side. The southern, or Nanaimo, field lies about 75 miles north of Victoria, the capital, with which it is connected by rail. The mines were opened at Nanaimo in 1863, and some of them extend under the Strait of Georgia, a distance of 2 or 3 miles. The coal, which is a good coking and gas coal, occurs in seams 5 to 12 feet thick. At Wellington, 6 miles north of Nanaimo, are other large mines said to furnish one of the best fuels

on the Pacific Coast. The Wellington seam is 10 feet thick, in places even more. Mines have been opened also at Alexandria, Harewood, and Extension. There are two productive seams, the Douglas and the Wellington, in this field. In some places both seams are worked; in some places the Douglas only; in others, only the Wellington.

The Comox field, about 60 miles north of the Nanaimo field, has not so far proved so productive. The coal seams lie nearly flat and there are said to be ten seams aggregating 29 feet 3 inches of coal, the seam worked varying from 5 to 8 feet in thickness.

Some coal occurs on Queen Charlotte's Island, farther north, and future investigation will no doubt show the presence of other fields.

COAL FIELDS OF EUROPE

ENGLAND AND SCOTLAND

140. The coal measures in Great Britain, as in the United States, are underlaid by a massive bed of conglomerate sandstone that is called the Millstone grit, and corresponds in position to the Pottsville conglomerate of the United States. It varies in thickness, from 400 feet in South Wales, to 5,000 feet in the Lancashire region.

The principal coal fields are as follows: That of South Wales, 1,000 square miles in extent, containing one hundred coal seams, seventy of which are worked. The region about Bristol contains eighty-seven coal beds, and a thickness of about 6,000 feet of coal-measure strata. In the forest of Dean, the thickness of the series is 2,400 feet, and contains twenty-three coal beds. There are several small areas in Central England, in Shropshire, Warwickshire, Leicestershire, and Staffordshire. The South Lancashire region, east of Liverpool, 220 square miles, with a thickness of 7,200 to 8,000 feet of strata, contains forty or more coal seams. The Derbyshire field, east of the field last mentioned, covers 800 square miles. The Cumberland field, on the west coast,

contains 258 square miles. The Northumberland field, on the east coast, contains 796 square miles. In this area is one of the most important coal-producing areas in Great Britain, including such well-known centers as Newcastle and Durham.

In Scotland, most of the coal comes from the lower Carboniferous strata, in the area between the Grampian range on the north and the Lammermuirs on the south.

Most of the English coal is bituminous, but anthracite occurs in the western and northern portions of the South Wales field.

The coal measures are variously divided in the different fields. In South Lancashire, the division is into a Lower, or Ganister, series, consisting of flagstones, shales, and thin coal seams; a Middle series of sandstones, clays, shales, and thick coal seams; an Upper series of shales, limestone, ironstone, and thin coal seams.

GERMANY

141. There are six coal fields in Germany, covering an area of about 3,600 square miles. The most important one, covering 2,800 square miles, is in the basin of the Ruhr, where there are sixty beds with a total thickness of from 150 to 200 feet of coal; the total contents are estimated at 45,000 million tons. The area enclosed by the rivers Saar, Nahe, and Blies, covering 460 square miles, is an important coal field. It contains eighty-two workable coal beds of a total thickness of 250 feet of coal, comprised in coal measures 20,000 feet in thickness. The Upper Silesian basin is a still larger producing area. It lies in the borderland between Austria and Poland, and is estimated to contain 50,000 million tons of coal.

Lower Silesia, Zwickau, and Aix-la-Chapelle are large fields. Smaller fields are those of Osnabrück, Ibben-büren, Minden, etc. Silesia has one seam 50 feet thick.

Besides its large coal output, Germany produces quantities of lignite. The largest lignite deposit is that in the Saale district, between Altenburg and the Harz. Peat is also used as a fuel in North Germany.

FRANCE

142. The coal production of France for 1899 was 32,862,-712 metric tons,* which came from fifty-two different basins in fifty-nine departments. The principal producing departments are Pas-de-Calais, 14,000,000 tons; the Nord and the Loire, 5,000,000 tons each; the Gard, Aveyron, and the Saône-et-Loire, over 1,000,000 tons each.

About 5 per cent. of the total production was anthracite, which was mined principally in the Nord, Isère, Saône-et-Loire, and Loire; 607,000 tons of lignite were produced, five-sixths of which came from Bouches-du-Rhone. Peat is produced to the extent of 100,000 tons.

There are 292 exploited concessions, of which 47 are lignite and 242 bituminous and anthracite. The deepest mines are in the Gard, one of which is 2,657 feet deep.

BELGIUM

143. There are two large coal basins in Belgium—the western and the eastern. The western field contains about 222,400 acres, the eastern about 108,800 acres. Anthracite and different varieties of bituminous occur. The thickest seams are about 3 feet.

The principal subdivisions of the coal measures in Belgium and North France, beginning at the top, are: (1) zone of gas coals, rich bituminous coals, with 28 to 40 per cent. of volatile matter, forty-seven seams of coal; (2) zone of *charbons gras*, soft coking coals, twenty seams, 18 per cent. to 28 per cent. volatile, well suited for making coke; (3) zone of the *charbons demi-gras*, twenty-nine seams, 12 per cent. to 18 per cent. volatile matter, fitted for blacksmithing and iron furnaces. These are underlain by the Millstone grit, and it in turn by a great thickness of limestone.

The total production of the Belgian coal mines from 1831 to 1890 was 609,559,350 tons, valued at $1,329,920,000. Since 1890, the annual production is about 20,000,000 tons.

*A metric ton contains 2,204 lb.

RUSSIA

144. The most important coal field in Russia is the Donetz basin, on the north shore of Azof. The Moscow field and Poland are important producers. The Asiatic Russian provinces produce considerable quantities of coal.

BRITISH INDIA

145. Coal of different grades is found widely distributed over British India. The principal mines are located in the Ranigunj district, Bengal; at Singarini, in the Nizam's territory; in the Lakhimpur district, in Assam; at Mohpam and Narora; in the central provinces and at Umaria, in the Central Indian Agency. The production for 1900 was 6,118,000 tons, which is nearly double the output of 5 years previous.

COAL FIELDS OF SOUTH AFRICA

146. In a paper read before the North of England Institute of Mining and Mechanical Engineers, in 1898, Mr. William Piele gave the following data:

"The South African coal field commences in Cape Colony, and extends over the Orange River Colony, parts of Natal and Zululand, into the southeastern portion of the Transvaal. The coal measures comprise gravels, clays, coarse and fine grits, and dark and light sandstones, interstratified with Carboniferous and micaceous shales and with seams of coal. The Transvaal coal seams vary in thickness and extent, and at the Great Eastern colliery there is a succession of coal beds 75 feet in thickness, which in a short distance divide into three or more seams. The coal is inferior in quality, splinty and dull in appearance, but the situation is convenient by railway to the gold mines along the Rand.

"In the Middleburg district, near the Delagoa Bay branch of the Netherlands railway, six distinct seams of coal have been found within a depth of 172 feet. A total thickness of 58 feet of coal has been found at 200 feet, and these

several seams outcrop in many places over an area exceeding 80 miles square. The total area of the coal field may be comprised within a line south of Krugersdorp to a similar line east of Grwelo, about 170 miles in length by 120 miles in width, covering an area of about 20,000 square miles. Owing to the shallowness of the overlying strata, and to the seams so frequently outcropping, the entire coal field appears to be free from explosive gas. The formation is also very free from faults, but is subject to perforations of intrusive igneous rock forming dikes, which often alter the bituminous seams into semibituminous and anthracite.

"The comparison of the qualities of the coal from three districts is shown in the following table:

Sample	Near Brugspruit		Near Bethel	Near Springs
Moisture	.15	.80	.30	.57
Volatile matter	24.86	27.80	41.23	14.10
Fixed carbon	64.25	64.10	52.16	63.00
Ash	10.67	6.50	6.31	22.00
Sulphur	.07	.80	trace	
	100.00	100.00	100.00	99.67
Yielding coke	74.97	70.80	58.47	

"On the northern side of the Netherlands railway, between Pretoria and Bronkhorstspruit, there are various patches of coal.

"The railway, just before it reaches Brugspruit, passes through the most important district yet explored. Excellent coke has been made at the Maggie mine. Some good coal has been found along Skeenkool Spruit, the six seams having the following characteristics: (1) a semibituminous character, sometimes like an anthracite coal; (2) and (4) usually thin; (3) variable; (5) of a splinty character, and now being vigorously worked at Witbank, where the bottom coal is excellent, and equal in every way to the best British coal (it has been proved by a bore hole to be 20 feet

in thickness, and the bottom coal is 11 feet 6 inches thick); and (6) is said to be of good quality, covering from 3 feet to 4 feet in thickness, but has not been worked.

"The strip of coal on the north side of the railway from Middelburg to Belfast is poor in quality, doubtless owing to the proximity of granite along the northern boundary or limit of the coal field, but the quality improves to the south. Near Belfast, on Paardeplaats, a colliery near Ermelo, a bed of oil shale has been discovered, and it is to be worked. On the southern side, there are no important collieries except the Fortuna, working a seam from 8 to 9 feet in thickness, belonging to a lenticular deposit, at a depth of only 45 feet. The upper 4 feet of the seam is splinty in quality, and the lower 4 feet a good bituminous coal.

"A group of small collieries (the Perseverance, Platkoppe, Transvaal, and Oceana) exists on the south side of Heidelberg, all working different sections of outlying coal. The important colliery district of Springs, near Johannesburg, is in this vicinity, and here there is a group of collieries fitted up with modern plant.

"On the frontier, at Vereeniging, on both sides of the Vaal River, but principally in the Orange River Colony, are the important Vaal River collieries.

"Further westwards, a series of beds of coal, about 200 feet in thickness, has been proved by a bore hole about 17 miles south of Krugersdorp. An average analysis of the coal between 313 and 390 feet gave: ash, 21.1; volatile matter, 44.0; fixed carbon, 34.9; while one bed at a depth of 513 feet, 3 feet 8 inches in thickness, gave: ash, 7.9; volatile matter, 48.9; fixed carbon, 43.2.

"The seams are mostly easily accessible, except, possibly, in the western part of the coal fields, with good roofs, practically no timber required, and little or no water to pump. Natural ventilation is usually relied upon, upcast pits being put down when extensions underground require them, and being shallow, except around the shaft, small pillars are left."

EXAMINATION OF COAL PROPERTIES

INTRODUCTORY

1. Scope of the Subject.—The subject here treated is the practical application in the field of what the student has studied in the subjects of *Surveying* and *Geology of Coal*, in so far as these relate to coal; and, in general, it may be said to cover all the work incident to testing and purchasing a coal property.

The presence or absence of coal is usually so easily ascertained, and coal is of such little value unless within reasonable distance of a railroad or local market, that prospecting for it in the sense applied to the search for precious metals is rarely undertaken. The work required will more frequently be to examine and report on properties where coal is known to exist, rather than to prospect for coal where its presence is unknown.

Practically all of America, Europe, Australia, and the seacoast, at least, of the remaining continents, has been covered by extended geological surveys, and it is probable that these have brought to light all the fields where the existence of coal would be of immediate value. The discovery of coal elsewhere would not be the object of special research, but only incident to prospecting for the more valuable minerals.

2. Division of the Subject.—No satisfactory division of coal properties into natural groups can be made. While

it is true that the methods and work in horizontal and pra
tically unfaulted deposits are simpler than in the inclin
and faulted fields, yet they shade so gradually into o
another that no sharp line can be drawn. The examinati
of a property of 3,000 acres is quite different from that
100,000 acres, and widely different from that of seve
hundred or a thousand square miles.

Since the properties that must usually be examined
those where coal is known to exist, and where the rocks
undisturbed and the seams flat or only gently pitching, th
will first be treated of, and attention afterwards called
methods applicable to inclined, contorted, and faulted sea

In the United States the first group will in general co
prise the coal fields east of the Missouri River, and the s
ond, the fields in the Rocky Mountain region and fart
west.

3. Thoroughness of Examination.—The expense,
other words, the time and labor, permissible on a prope
is proportioned to its value and cost of opening. If one tr
can be bought for $5 an acre in fee simple, the expendit
of $1 an acre in detailed examination would hardly be co
tenanced by the investor, whereas that sum laid out
another tract valued at $500 or more per acre, or on
involving an outlay of a quarter of a million for openi
would be insignificant. The object in any examination i
determine the suitability of a particular property for a p
ticular purpose; when this is done, any further outlay
wasted.

With low-priced properties bought for investment, i
generally enough to measure the thickness of the seam
seams, test the quality of the coal where openings exist,
form a rough estimate of the length and cost of the railr
required in opening it.

With high-priced lands secured for immediate devel
ment all the seams above water level should be opened
measured, and where the seams are of workable thickn
the coal should be analyzed. At times drilling should

undertaken to prove the continuity of the seam back from the crop line, or to explore for seams below the surface; and levels should then be run to determine the dip, strike, synclines, and anticlines. Faults should be searched for and located; the best method of working determined, and an accurate, detailed estimate prepared of the cost of opening and operating the property. Between these extremes, almost any combination of circumstances or requirements may be met, and the prospector must use his judgment in determining what investigations are necessary, what methods to pursue, and how much time may properly be spent on the property in hand.

EXAMINATION OF A PROPERTY

PRELIMINARY OFFICE WORK

4. Before visiting a region with which he has had no previous familiarity, the prospector should gather information from every available source. Maps are of prime importance, and tracings should be made of them. It is advisable to carry two or more blueprints, preferably linen-backed, of each tracing, one for use in the field, the other on which to enter at night the notes taken during the day.

The publications of the various state geological surveys, and the files of the technical and scientific press, to be had in any large library, should always be consulted, and, when necessary, notes taken therefrom. A letter addressed to the chief mine inspector or to the state or provincial geologist, and directed to the state capital, will usually be promptly answered, and the desired information given.

In many localities recourse must be had to reports of private individuals or the publications of the United States or other government geological surveys. A request made to the Director of the United States Geological Survey at Washington, D. C., or the director of the geological survey at any other state or national capital, will secure a price

list of bulletins, reports, monographs, and geological folio from which the prospector may select such as suit his pa ticular case.

The United States geological folios are of extreme value f such investigations, being really complete geological repor of the areas covered, with topographical and other ma showing all the natural and economic features, togeth with sections and analyses of coal seams, iron-ore deposit and the like. These folios or reports may be had for 25 cen each, and the survey publishes a skeleton map of the Unit States showing the area covered by each.

The prospector must not, however, be prejudiced for against any particular property or field by the statemen made in the reports of the geological surveys, or reports ma on the same property by any other person. Such surve may have been made some years previous, when the regi covered was but little developed and the lands had sm value. Some of the important coal fields of today lie in se tions that have been either ignored by geological reports actually condemned by them. All sources of informatio verbal as well as printed, should be used impartially guides, and their conclusions accepted or rejected only aft a thorough, careful, independent examination.

FIELD WORK

5. Preliminary and Final Examinations.—The inv tigations in the field may be divided into **preliminary a final,** the one leading up to the other. The prelimin examination should be conducted as a more or less ha weeding-out process to show whether the property is poor that it ought to be condemned, or sufficiently good warrant a detailed or final examination. The prelimin examination usually consists in ascertaining the quali thickness, and extent of the seam, its location for openi and whether in general it meets the requirements of purchaser. This examination can usually be carried on

the prospector alone, but when samples must be taken for analysis a helper is desirable. If the preliminary investigations are satisfactory, the final examination is then undertaken. In prospecting unexplored regions, owing to the distance from supplies and to save time, the preliminary and final work should be carried on together as far as possible.

PARTY

6. According to the magnitude of the work and the conditions surrounding it, the **party** may consist of any number and may include guides, cooks, camp followers, laborers, pack mules, or wagons carrying instruments and supplies, and even a military escort. In China, prospecting parties have numbered 200 or more persons, and have been the subjects of international correspondence.

INSTRUMENTS

7. The **instruments** used will vary, but they should be carried in sufficient variety and quantity to meet any contingency, unless it is certain that all wants can be supplied on the spot or within a reasonable time. For preliminary work a foot-rule for measuring the thickness of seams, a pick for taking samples, and sacks for holding the same, together with notebook and pencils, are all that are absolutely necessary. For more detailed work, there should also be carried an aneroid barometer, pedometer, pocket compass with folding sights, a clinometer, hand level, hammer, bottle of acid, a small set of drawing instruments, ink, two triangles, horn protractor, scale, 50-foot tape, some tracing cloth, and drawing paper. Paper ruled in squares of eight or ten to the inch is useful in sketching in topography. Nothing shows up a property so well as photographs, and if the prospector can use a camera, it should be invariably carried and pictures taken of all outcrops and of places that might prove desirable for locating a plant.

8. The **aneroid barometer,** Fig. 1, consists of a circular metal box or vacuum chamber, hermetically sealed, one side of which is a corrugated plate. This plate, under the action of a stiff spring, rises and falls according as the pressure of the atmosphere decreases or increases, and this slight motion is greatly multiplied, and transmitted to an

Fig. 1

index pointer moving over a graduated dial on the outer face. Most aneroid barometers have two concentric scales, as shown in Fig. 1, the outer, or the altitude, scale, starting from 0 and giving the elevation above sea level, to the nearest 10 feet and the inner, or mercury, scale, giving the atmospheric pressure in inches, tenths, and hundredths, usually from 27 inches to 33 inches, corresponding to the

readings of the mercurial barometer. The outer, or altitude, scale is often made so that it can be moved by the milled screw shown and its zero set to correspond to any desired reading on the mercury scale.

Aneroid barometers are graduated to indicate elevations of 3,000, 10,000, or even 20,000 feet above sea level, and a barometer should be chosen to suit the region to be visited. Usually one reading to 5,000 feet above the sea level, and with a 2-inch or 2½-inch face will answer all purposes. Nothing is gained in accuracy by having a very large instrument. Some barometers have a small thermometer attached to the dial, and from its reading a correction for temperature can be made. This correction, however, is usually omitted in preliminary work. Formulas and tables for determining it are to be found in most engineers' pocket-books.

9. Care of the Barometer.—The barometer should be carried in a leather case and not removed from it. It should be protected from sudden changes of temperature, and when observations are made, it should have the temperature of the surrounding air. It should be carried so as not to be affected by the heat of the body, and read where not exposed to artificial heat. It should always be read in a horizontal position.

10. Accuracy of Barometric Elevations.—The barometer should not be relied on to give the exact elevation above or below sea level, but only the relative difference in elevation of two points not far apart, and then only when the readings are taken in a short time interval.

The line of mean tide at Sandy Hook, New York Harbor, is the starting point for all elevations in the United States. It is evident that two barometers set to correspond and then carried to two different places having the same elevation above sea level will not agree in their readings unless atmospheric conditions at the two places are absolutely identical. This variation in reading may be as great as 500 feet or more, and even at sea level the reading of the

barometer varies owing to the constantly changing pressure of the atmosphere. However, the difference in elevation of two points distant from each other but a few miles may be determined satisfactorily for preliminary prospecting work, if the readings are taken not over 30 minutes apart, and the atmospheric conditions are reasonably constant (no storm coming up).

11. Use of the Barometer.—There are two general methods of using the aneroid barometer in field work, (1) the single, and (2) the double.

1. *Single Method.*—In this method the observer, after reading the barometer at some bench mark of known or assumed elevation, carries it as rapidly as possible to the point where the elevation is desired, and again reads it. The difference in these readings is the difference in elevation of the two points, with of course no allowance for any change in the meanwhile in pressure, humidity, or temperature. The difference in elevation of the two points, added to or subtracted from the known elevation of the first, gives the elevation above tide (usually written A. T.) of the second. For more accurate work, the temperature may be taken at both stations, and the proper correction taken from tables for that purpose. The observer moves from point to point, reading the barometer and recording the results. He may reduce these readings at night, after returning to camp, but preferably they should be reduced as soon as taken, so that any unusual error may be corrected by a second observation.

The readings may be noted thus:

SMITH PROPERTY, MARION COUNTY, OHIO

May 3, 1902

	Feet
E seam, Hoover farm, 9.30 A. M., clear, barometer..	1,460
Bench mark No. 1, 9.10 A. M., clear, barometer......	1,210
E seam above B. M., No. 1........................	250
Elevation B. M. No. 1 (A. T.).....................	1,090
Elevation E seam, Hoover farm (A. T.)............	1,340

In the single system more accurate results are obtained when the observer passes as rapidly as possible from one station to another, stopping at each station for half an hour or so, reading the barometer at each place both on arrival and departure. If there is any difference in the readings, it denotes changing atmospheric conditions. From the differences in readings obtained at the various stations a continuous correction curve can be constructed on cross-section paper, from which the correction for any hour of the day may be obtained. If the observations are taken a second time the same day, say on return from the field in the afternoon, and a second correction curve made out and the average of the morning and afternoon results taken, very accurate elevations may be obtained.

It is commonly supposed that the mean of two independent readings always gives a closer approximation to the true altitude than a single one, but this is incorrect. Of course, the average of a large number of single readings will probably be nearer the truth than any single one, because in time the barometer will fluctuate as far one way as the other from the true reading.

2. *Double Method.*—In this method two observers and two barometers are used. The readings of the two barometers at the bench mark are compared at starting in the morning, and if not the same, the scale on one of the instruments should be moved until they agree. It is well to make another comparison at night to see if any jar has disturbed the barometer during the day.

One observer remains at the bench mark throughout the day and reads the barometer at regular specified intervals, say every 15 minutes; he may also note the state of the weather and temperature, though this is not nearly so essential as in the single system.

The field observer moves from point to point, and after reading the barometer, notes the reading and the time, in his field book.

As it is unusual for the atmospheric conditions to remain constant, the barometer at the bench mark may vary during

the day 100 or 200 feet, but since these changes affect both barometers alike, they are eliminated by comparing the readings taken at the same time at the bench mark and in the field. The difference in elevation of stations may be reduced in the field to detect any large errors, but the final reduction must, of course, be left until night, when both observers are together. The method of reduction is shown below for each of these methods.

	Feet
Single Method—	
Opening No. 1, Smith farm, 10 A. M., barometer....	1,320
B. M. 10.30 A. M., barometer	1,060
Opening No. 1, Smith farm above B. M............	260
Elevation B. M. (A. T.)............................	980
Elevation No. 1, Smith farm (A. T.)................	1,240
Double Method—	
B seam, Jones farm, 4.05 P. M., barometer..........	1,320
B. M. 4.05 P. M., barometer.........................	1,190
B seam, Jones farm above B. M.....................	130
Elevation B. M. (A. T.)	980
Elevation B seam, Jones farm (A. T.)	1,110

Observations taken by the single method 6 hours apart would have shown the openings on the Smith and Jones farms to have the same elevation, while the more accurate double method gives a difference of 130 feet.

The double method will give good results where the stations are as much as 10 miles apart when sudden and distinctly local changes in atmospheric conditions do not occur.

12. The **pedometer**, or **passometer**, is an instrument, shaped like a watch, Fig. 2, for registering the number of paces taken while walking. The instrument is worn in an upright position attached to the belt; the jar given by each step acting on levers and springs inside the pedometer case turns a ratchet wheel that in turn moves an indicator on the face of the pedometer. The instrument may be

adjusted to any length of step by means of a screw. The face of the pedometer is graduated so as to register the distance traveled in miles. The accuracy of the results is proportional to the uniformity of the steps; that is, they should not be alternately long and short. When the instrument is adjusted to suit the length of pace of any particular individual and natural regular steps are taken, it will measure distances within about 2 per cent., or the error will not exceed, say 100 feet per mile, and is amply accurate for all prospecting work.

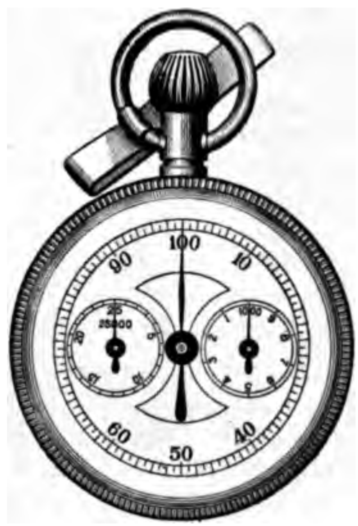

FIG. 2

To determine the length of a pace, measure off as long and level a base line as possible, and walk over it with the natural step and usual speed. The distance divided by the number of steps gives the average length of pace, and may be used to measure distances by keeping a record of the number of paces between points.

The following table, from Johnson, gives the average length of step for different sized persons:

Height of Person		Length of Step	
Feet	Inches	Feet	Inches
5	1	2	5½
5	3	2	6⅛
5	5	2	6¾
5	7	2	7
5	9	2	7⅝
5	11	2	8¼
6	0¾	2	8⅝
6	2¾	2	9⅛
6	5	2	9½
6	7¼	2	10⅛

On slopes the step is always shorter than on level ground, whether one goes up or down, as shown in the following table, the average length of step being taken as 2 feet, 7¾ inches.

Slope	Length of Step Ascending		Length of Step Descending	
Degrees	Feet	Inches	Feet	Inches
0	2	6⅛	2	6⅛
5	2	3⅜	2	5⅛
10	2	0⅛	2	4⅛
15	1	10 1/16	2	3¾
20	1	7⅜	2	2½
25	1	5¾	1	11⅝
30	1	3	1	7⅜

13. The **hand level** is a small telescope with a level tube on top, Fig. 3. The bubble in the level tube, by means of a mirror, is visible at the same time as any object toward which the instrument is directed. When the reflection of the bubble is bisected on the object glass, the eye of the

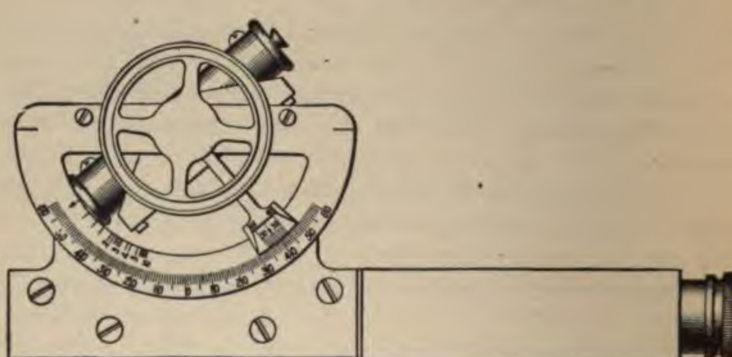

Fig. 3

observer is on a level with any point or points that may be cut by this line. It should not be relied on for long sights, but is valuable for preliminary leveling, sketching topography, tracing horizontal seams, etc., and does fairly good work if supported firmly when in use.

14. The **compass** should be of the ordinary pocket form, with cover, and preferably with folding sights. See Fig. 4.

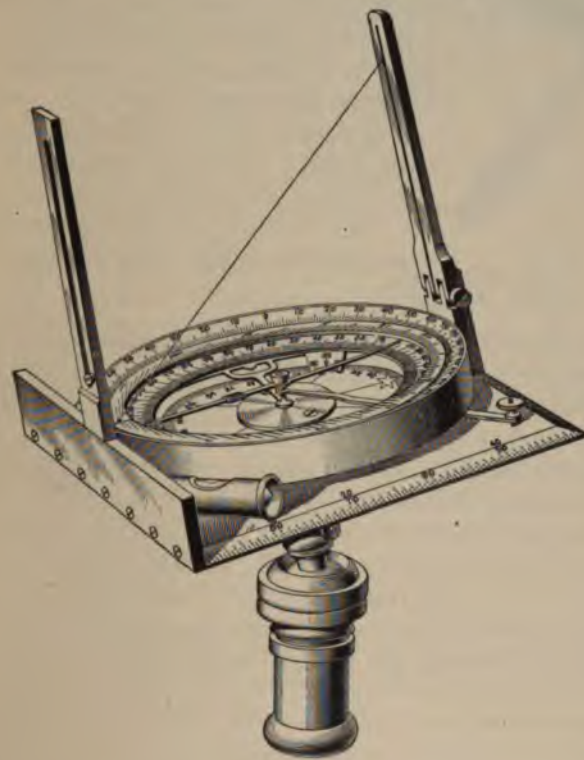

FIG. 4

15. Tools for Sampling.—For taking samples, a small miner's pick is best. One with a removable handle that may be screwed or locked in can be made to order and is more portable. For holding samples, small coin bags are convenient, paper sacks are often used, and if there is any reason to believe the samples may be tampered with by interested parties, sealing wax should be used to secure them tightly.

On extended surveys, in tracing seams over long distances, it may be necessary for comparison and identification to secure specimens of the rocks overlying or underlying a given seam, and for this purpose a geologist's hammer, Fig. 5, is useful, one edge being chisel-shaped for splitting shales and slates.

FIG. 5

A bottle of dilute hydrochloric (muriatic) acid may be of use in identifying limestones which effervesce under its action, and on distant exploring expeditions a fairly complete laboratory outfit might be taken.

16. Notebooks.—A liberal supply of **notebooks** should be taken, consisting of small ones for the pocket and use in the field and a larger one for permanent record. Full notes should be taken in the field, and at night entered in the permanent record, and any corrections or additions should be made while the subject is fresh in the memory. If anything important is found to have been omitted, it should be taken up the next day, if possible, so that the work may be completed as it progresses. Another advantage of posting the day's work at night is, if the field book is lost or destroyed, only one day's work will have to be repeated.

OPTIONS

17. A coal company about to acquire new property, a corporation about to embark in the coal business, or a syndicate of capitalists seeking investment in coal lands, will usually have secured *options* on various tracts of land in some section of the country previously decided on, the owner of each property furnishing a more or less full description of the field, together with a map.

An **option** is a written agreement by which the owner of a property agrees to sell the same to the second party thereto at a specified price, if payment is made within a stipulated

time, usually 30 to 90 days. Within this time the property should be examined, and if not satisfactory, the grantor of the option should be given written notice that the land will not be taken. If satisfactory, a certain sum is paid the landowner to bind the bargain, and after the surveys are completed, area calculated, and titles examined, the remainder of the first payment, usually one-third of the entire cost of the land, is made and the deed for the property given. If, for any reasonable cause, the examination is not completed within the time set in the option, a renewal or extension will generally be granted.

The option, besides stating the price per acre and terms of payment, sets forth what seam or seams are to be conveyed and what mining rights and privileges granted, and in these points custom varies greatly in different localities.

In some few instances the land is bought in fee simple; that is, everything, coal, surface, and buildings, pass to the purchaser. This is the common case with the cheaper lands. Usually all the coal is sold, the landowner reserving the surface for farming, or only one seam may be conveyed, as in the Pittsburg Region, or again, all the coal above or below a certain seam is granted.

18. The mining rights should be clearly and distinctly set forth, stating how much per acre, if anything, the purchaser will have to pay for land on which to build the plant, and above all, that he is released from all liability to the landowner for injury to the surface or anything thereon, caused by working and removing all the coal. This is of the highest importance, since it is obvious that the value of the property is materially lessened for mining purposes if the pillars cannot be drawn for fear of injuring the surface. Frequently a block of coal is reserved under buildings for their protection, but such reservations should be avoided if possible, as they make trouble in laying off work, particularly when in the interior of a field. Sometimes a few acres near the crop are reserved as a source of supply for the family or neighborhood. The option should also provide

certain definite water and timber rights, and release operator from liability arising from the contamination water supplies by the waste of the mine. In timbe regions, it is not unusual for all the trees suitable making props and wooden rails, or those under a cer size, say 10 inches diameter, to be granted the company.

When the coal is reached by a shaft, all coal under given farm or tract is purchased; but where the coal c on the property and only a portion of the farm or trac underlaid, the option should provide that the purchaser the right to take the coal within the crop line. This r be the extreme outcrop, or an arbitrary line parallel ther and any distance inside, usually taken far enough to ins that all the coal secured is solid and unaffected by weatl ing. This distance varies from 30 to 100 or more feet; flatter the hill, the greater the distance, and is usually spo of as the *30-foot crop* or *100-foot crop.*

The option should further grant to the prospective p chaser the right to enter on the property to make all ne sary surveys and explorations with pick and shovel or drilling, which in his judgment may be necessary to prop prove its value.

This subject has been gone into in detail, because examining prospector will frequently be called upon to that the options are in "good shape," that is, convey to company all the rights and privileges necessary for che and successfully working the property.

Form of Option

This agreement made and concluded this....................da
..................A. D....., by and between.....................
of the County of..................in the State of................
party of the first part, and........ ....
of the County of.......... ....in the State of...............
party of the second part, Witnesseth:

That, in consideration of the sum of one dollar in hand, paid by said second party, the receipt of which is hereby acknowledged said party of the first part hereby bargains and sells unto the party of the second part, ...heirs and assigns, at the optio the said party of the second part, ...heirs and assigns,

agrees to convey, by good and sufficient deed, clear of all encumbrances, to said party of the second part, ...heirs and assigns, within one year from date, or sooner if desired, upon payment of the purchase money, all the coal and other minerals contained in and under all that certain tract of land situate in.....................Township, County and State aforesaid, bounded and described as follows:

....
....
....
....
....
containing..acres, be the same more or less.

And said party of the second part is hereby granted the right to enter at will upon said premises and dig for coal, etc., and make such explorations as......may deem necessary to thoroughly test the same, and to dig and mine coal for market, and to build and use, and authorize to be built and used, such roads, railroads, tipples, chutes, buildings, and other improvements, without liability for damages, as are usual and necessary for mining, shipping, and transporting coal, minerals, and other commodities. Also is hereby granted the right to move, carry, and transport, by railroad or otherwise, any coal and minerals taken from other lands, and other commodities, over, across, through, and beyond the lands above named. Right of way for railroad, of lawful width and as may be located, is hereby granted to said party of second part, ...heirs and assigns. In consideration of the purchase of the property herein described it is agreed that the vendee, his heirs and assigns, shall take the same free and clear of all obligations to support the surface. Possession is hereby given for the purpose of this contract.

In Consideration Whereof, the said party of the second part hereby covenants and agrees to pay, or cause to be paid, unto the party of the first part, ...heirs, administrators or assigns, the sum of...dollars on the execution and acknowledgment hereof, and the remainder of the entire proceeds calculated at the rate of....................dollars per acre on the.................day of...................A. D....., in case, after full examination, the property is found to be satisfactory to said party of the second part. The quantity to be ascertained by survey of the crop line of coal measures, the vendee being granted the right to reject such of the measures as may not be satisfactory. This option is to run for......................months, and the acceptance of the property is to be evidenced by a written notice to that effect, within such time and not otherwise.

IN WITNESS WHEREOF, the parties have hereunto set their ha
and seals, this the day and year above written.

.... SEA

Witness· .... SEA

....

.... SEA

....

.... SEA

Received, ...1......, ...on wi
contract...
....

........................COUNTY, *ss*:

Personally appeared before me, a.............. ....
in and for the County of..................and State of...........
....
who in due form of law acknowledged the foregoing instrument to
................act and deed, with the intent that the same might
recorded as such.

IN WITNESS WHEREOF, I have hereunto set my hand and offi
seal, the...............day of....................A. D., 1......

....

SELECTION OF A PROPERTY

19. Unless the prospector is called on for a full a detailed report on some one particular property, he will given instructions to examine a number and select the from for more careful study one or more that seem mo nearly to meet the requirements of his employer. As company cares to pay for lengthy reports on tracts th simple inspection will prove unsatisfactory, the prospec should carefully note in writing and thoroughly understa just what reasons will cause the rejection of any proper These may be countless; for instance, the seam may

a gas coal and not a steam coal, and therefore perhaps unsuited to the trade of the company, or the coal seam may be too thin or too full of slate or sulphur, or too far above or below railroad grade. There may be no suitable place for building a plant, or the branch railroad required to reach the property may be longer than the company cares to build.

With purely commercial considerations, such as the selection of properties in a certain field or on a certain line of railroad, the prospector has nothing to do, these matters being left to the management of the company, and it is not unusual for the prospector to have to choose the best from a series of relatively poor properties on one road, when a short distance away, but on another line, much better coal could be had at the same price. The prospector should bear in mind that his work must be kept subordinate to the financial side of the problem. Will it pay ? is the question, first, last, and always, and it matters not how good the coal may be or how favorably situated for opening, if it cannot be made to yield a reasonable return on the investment it is of no value. Therefore, the first duty on reaching any group of properties is to reject as rapidly as possible all such as are obviously at variance with the instructions. It is advisable to notify the home office at once why certain properties are not up to the requirements, so that the options may be returned to the grantor or instructions issued for further examinations.

20. This report is preferably in the form of a letter to the management stating, for illustration:

I find the two openings on the Smith tract show but 29 inches of coal, and on the Landis property 2 miles northeast, while the seam measures 42 inches, it is so interstratified with slate (6½ inches in three different partings) as to be worthless.

The Jones 4,200-acre property probably contains good clean coal, but, as the Mahoning sandstone is here at water level, the seam must be at least 150 feet below railroad grade, and as the valley is very narrow, it will be difficult to open.

A branch about 5 miles long, with heavy grades, will open this property at the back above water level, but fully 75 per cent. of the

coal would have to be mined to the dip. The seam at the Wesser opening measured 4 feet 7 inches, free from dirt and slate, and showed only minute patches of pyrites. If the analysis of the sample taken from the full section of the seam, sent you by express today, bears out the appearance of the coal, a detailed examination might be advisable, as I am reliably informed the property can be bought for about $15 per acre less than the price quoted.

This is sufficient to show the management that the Smith and Landis properties are out of the question, and that the Jones is also not available, unless it can be had at a price sufficiently low to offset the cost of the branch railroad and the increased expense of operation due to mining to the dip. It is well to note that quality and location are the prime factors in determining the value of a seam. It should also be borne in mind that coal that is today considered poor in quality and location may be the good and desirable coal of the future, and much depends on whether a field is purchased for investment or immediate development. These points the investor decides.

Having sorted out and rejected the properties plainly unsuitable, the prospector next considers those properties that in his judgment will bear more careful investigation. If the property is well located for opening, and, in general, suited to the needs of the company, the next step will be to test the quality of the coal, and this test will lead to the rejection of such as are not found satisfactory.

TAKING SAMPLES AND SECTIONS

21. Sections. — For taking samples and sections an assistant is almost indispensable. The **section** should be taken first, and consists in a measurement of the seam and interstratified impurities, together with a sketch. The pick should be used to make sure that the roof and floor are accurately determined. In many small mines the bottom bench of coal is not taken up, or roof coal may not be taken down, but left up to support the draw slate above; it is, therefore, well to examine any ditches for a bench of coal

underlying the apparent floor, and any places where the roof has fallen, for a portion of the seam overlying that left up. The results should be sketched and noted in the field book, as in Fig. 6. *1*, heavy draw slate, shows 14 inches elsewhere with sandstone above; *2*, a bone-like coal, separated readily from *3*; *3*, good clean bright coal, showing occasional

FIG. 6

streaks of mother; *4*, soft gray slate, thins to 1 inch in places; *5*, a much harder and more blocky coal than *3*, showing particles of pyrites near top; no trace of sulphur balls and bottom (mining) clay apparently clean; *6*, measures 3 feet 10 inches in ditch, with limestone below; weathers rapidly.

22. Samples.—The sample for analysis is taken by chipping with the pick a section of uniform area, say ½ to 1 square inch, from roof to floor, rejecting such portions as would be thrown out in mining. In Fig. 6 these would be the bone and slate. The assistant holds a paper box or shovel about 6 inches below the pick point to catch the chippings made. The face where the sample is taken should first be scored deeply with the pick, to remove all traces of soot, weathered coal or powder smoke, and provide a fresh, clean face. Care must be taken not to get too little of a hard streak or too much of a soft one, either being apt to be

higher in ash than the average of the seam. The chipp are then placed in a paper bag, or, preferably, a coin with a piece of paper bearing the number of the sample, n of seam and mine, and date, securely tied, and, with o samples, made ready for shipment to the chemist.

In the case represented by Fig. 6, it would be well to five samples. First, one of the entire seam, rejecting the slate, that is, a sample of portions *2*, *3*, and *5*; then of the bone alone; next one of each of the two ben separately, and, finally, one of the lower portion of bottom bench. This will accurately locate the impur and show if the bone coal must be left up or the mi slack thrown out (the sulphur in a seam often being centrated at the bottom) to improve the quality of the s as a whole. This, however, is very rarely done. M small banks or mines are not in over 200 or 300 feet from light, and have but few cross-entries, but it is well to samples from at least three places in each opening as rer from one another as possible, in order to obtain an ave of the mine. If each sample is analyzed separately, an is obtained as to the variation in quality within short tances, but as this is expensive, it is customary to place the samples from any one mine in the same sack and m one analysis do.

23. Samples should be taken under good cover where coal has not been acted on by the weather, as atmosph agencies tend to diminish the percentage of volatile ma and sulphur, showing an apparent increase in ash. If place where the sample was taken showed signs of weat ing or was wet, these facts should be noted in the field b because in neither case will the analysis fairly represent coal. In the first instance the weathering will cau decrease in the percentage of volatile matter and sul and an increase in ash, and in the second case the sul compounds in solution in the mine water are apt to deposited on drying the sample, causing an increase in amount of sulphur. All openings showing coal of work

thickness should be sampled and analyzed, and if enough do not exist to fairly show the character and quality of the coal, others should be made. How many is a question to be decided by the nature of the seam, its reputation, so to speak, for uniformity, and the value of the land. A seam notoriously variable or generally poor, such as the A seam of the Lower Productive measures, requires more careful sampling than the Pocahontas seam, which is very uniform over wide areas, both in thickness and quality. It is also apparent that land costing $500 an acre is worth more and demands more care in examination than that costing but $5. Also, the object to which the coal is to be put will have weight, particularly if used for coke making. Here, constancy as well as a low percentage of sulphur and phosphorus is of prime importance, and as these elements in coal vary greatly in short distances, more numerous samplings would be required than if the coal were to be used for steam raising.

If the sections and analyses obtained from openings about ½ mile apart agree fairly well, no others will be needed, unless made from cores obtained by the diamond drill. Samples from cores are best taken by a file or sharp knife, imitating, on a small scale, the work of the pick in securing samples underground.

FINAL FIELD WORK

24. The nature and character of the final field work will vary according as the property is held for investment or purchased for immediate development. In the former case the work will be more or less roughly done with the instruments described to determine the number of seams, their continuity, quality, and approximate extent, but in the latter case, the final examining and preliminary development work may well be carried on together with regular surveying instruments and full corps of engineers, saving time and expense. In either case a rough map of the property is necessary.

MAPS

25. How Obtained.—In the majority of cases a map is supplied by the owner of the property, but if not, a list of the farms, giving the individual owner's name and acreage under which the coal is for sale, will be furnished, and application to the county surveyor at the county seat will frequently lead to some map in his office from which a blue-print may be secured.

If the county surveyor has no map of the property, he can usually prepare one from the descriptions as recorded in the deed books cheaper and quicker than the prospector, but if this is impossible, a map must be made, and here procedure varies according to the location of the property.

26. System of Metes and Bounds.—In many sections, as for instance in the eastern part of the United States, and particularly in southern Pennsylvania and northern and

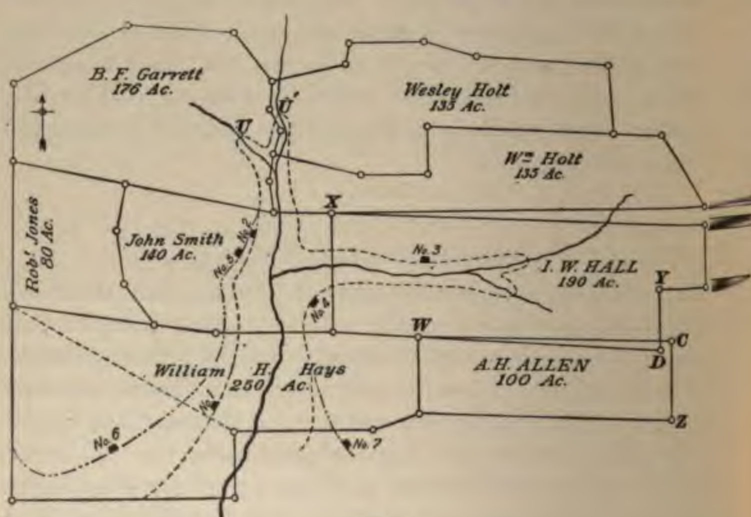

FIG. 7

central West Virginia, the tracts of land offered for sale generally comprise a number of farms of about 100 acres

each, and each landowner will have a deed or series of deeds for his property. It is well, therefore, to visit each farmer and obtain a tracing of any map he may have, noting thereon the bearing and length of each line and the kind of corner, i. e., oak, chestnut, stone, post. If the landowner has no map, copy from his deed the description, that is, the *metes and bounds*. If no deeds are forthcoming, inquire from whom the property was bought, and look for a description in the transfer to him as recorded in the county court house. If no description whatever of this particular farm is obtainable, the land may be located well enough by the surrounding properties, that is, although you do not have the bearings and distance of John Smith's property from John Smith's deed, you do have it from that of Robert Jones and the other abutting landowners, Fig. 7.

These surveys, of which descriptions have been obtained, may have been made at various dates extending over a long period, and a line surveyed 100 years ago as N 50° E may appear as N 47° E later, or the same description may have been used for one transfer after another, so that the date of the deed tells little about the date of the survey, and the proper allowance for variation cannot usually be made. Errors in recording and copying are common, and a line surveyed as N 69° W 74 poles may appear as N 74° W 69 poles or even N 47° W 69 poles. When these discrepancies occur, and they are very common, after having gathered the descriptions from the landowners or deed books, map each property separately on a uniform scale. Correct any obvious errors in the survey of one property by the corresponding line in another, that is, if a certain line given in Smith's description as N 74° W 96 poles does not close his property, while it will close on N 47° W 96 poles, the bearing and distance of this line given in the Jones survey, the latter is probably correct and should be used, the error being due to copying. After all precautions are taken to eliminate errors due to copying, the surveys will rarely close, because of careless field work on the part of the surveyor. Next, make a tracing of each piece of property,

each on a separate piece of tracing paper, and endeavor to fit the tracts together as best may be. No rules can be given for this, and nothing but the judgment of the engineer will tell him how much Hall must overlap on Allen, or how wide a gore or unclaimed strip must be left between Holt and Hall, Fig. 7. Of course, no laps and gores actually exist, the apparent ones arising only from errors of survey and recording.

27. In Fig. 7 the lines *XA* and *XB* are the same, as the corners are identical in both deeds; the length the same, but the bearing different. *C* and *D* are the same, an oak in both deeds, though the bearings and distances *WC* and *WD* are different, but the bearings *YD* and *CZ* are the same, showing this to have been originally a continuous straight line. After the separate tracings are fitted together as well as possible, they should be firmly fastened to the table and a tracing made of the entire area. When discrepancies exist, as at *A B*, *C D*, Fig. 7, either corner may be taken as correct and the discordant lines adjusted. In this case, if *A* is taken as the true location of the corner, the property line will be *VA* and not *VB*.

28. Scale.—The scale on which such a map should be drawn varies, but for medium or small properties that of 40 rods to the inch is convenient, while for large tracts even 80 rods to the inch will give a map too large to be easily handled in the field. In such case, it is probably better to use a scale of 40 rods, and make the map in two sections. Where a tract is as large as 200 acres, it is advisable to place on the map in dotted lines the various subdivisions as they appear from the owner's deeds, he usually having acquired his property by the purchase of several smaller lots.

29. Rectangular System. — In all sections of the United States and Canada where the rectangular system of surveying and laying out of land has been followed, map making is extremely simple. Each property, Fig. 8, is a

square or parallelogram, and will generally be some multiple of 40 acres in extent.

An easy method is to lay off a series of squares ½ inch on the side to represent a number of 40-acre tracts, and mark

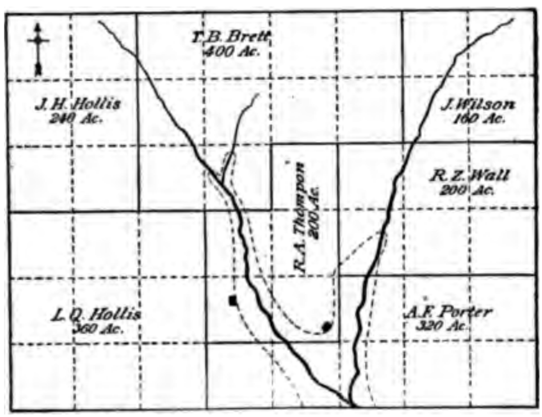

FIG. 8

each property thereon. After covering the field, this rough map can be enlarged to any desired scale.

30. Topographic System.—In many localities, as for instance in the southern United States, the tracts to be inspected are not infrequently of great extent, and, being parallelograms with no subdivisions, a map showing only the boundaries is useless because of the great area to be covered. Recourse must be had to the topographic sheets of the United States Geological Survey, and the outlines of the property fitted on as best may be. These sheets may be had on prepayment of 5 cents each to the Director of the United States Geological Survey, Washington, D. C. They are usually drawn on a scale of 1 : 125,000 ($\frac{1}{125000}$), or about 2 miles to 1 inch, and each map covers, approximately, 950 square miles, and shows the streams, main roads, railroads, important artificial landmarks, such as towns, country

churches, etc., and the contours for every 100 feet. T latter feature is important, showing the dividing ridg which may be anticlines, the width of bottom lands, an therefore, the available sites for plants. Since contou denote difference in level, they give the grades of any ra road required to reach the property, and even the appro mate length of any tunnel needed thereon, and all with the limits of accuracy required in dealing with low-price properties.

31. For more detailed study these maps may be enlarge by means of a pantograph, or by division into squares th are subsequently enlarged, but they answer all ordinar

FIG. 9

requirements as they are, even to the tracing of the outc of seams. In Fig. 9 is reproduced a portion of a topograp

sheet having every other contour and a number of the streams omitted. In the original maps the contours are brown and the streams blue, and every fifth contour is made heavier than the others; the roads are shown by dotted lines, and the houses by small, solid black squares. The property shown on the map, Fig. 9, was a colonial patent. The corner *C* was at the junction of two streams. *D* was the oldest and largest poplar tree for several miles, and its location was established by taking its bearing from the junction of the streams east of it, the distance being paced several times, checked by a pedometer, and the average taken. *B* was located by a traverse survey, made with compass and pedometer, from the junctions of the streams shown nearest thereto on both sides of the ridge. The corner *A* could not be found, and was located on the map by its bearing and distance from both *B* and *D*. The property might not have been located within a thousand feet or even half a mile one way or the other, but this was accurate enough for a tract of over 200,000 acres and valued at less than $2 per acre.

32. Methods in Other Countries.—In foreign countries, more or less detailed maps, similar to that shown in Fig. 9, are obtainable at the office of the geological survey, or are issued by the war department.

33. Unsurveyed Regions.—In regions previously unexplored and of which no maps exist, it may be necessary, if the preliminary examination shows the coal to be sufficiently valuable, to make a map. If regular surveying instruments are obtainable, they should be used, but, if not, the pocket compass and pacing or the 50-foot tape must serve. Where the outcrop follows the course of a stream, this latter should be traversed, the stream being used as a base for sighting to and locating the crop. If the seam pitches or the lay of the ground is such that the coal outcrops several miles back from the stream, or in cases where no watercourse serving as a base exists, though the compass and pacing will always

give good results, yet there may arise cases, particularly in locating isolated openings or other objects, in which resort to triangulation is advisable.

With pitching and highly contorted seams, where the geological structure of the region must be worked out, the surveys should always be made with transit and tape or stadia measurements, in order to furnish an accurate map as a basis for subsequent investigations. The stadia is to be preferred in measuring, because, while not so accurate as the tape, it permits of much greater speed. The tape may be used to measure between stations, on what may be called the main line of the survey, and points on the crop of the coal or other strata, openings, bends in the stream, or other objects should be located by side shots with the stadia.

In very large areas remote from railroads, all the prospector is supposed to do is to prove the existence and quality of the coal seams, making only such instrumental or sketch maps as may be necessary to this end. These sketch maps may be checked later, when more detailed and accurate maps are made for purposes of railroad location, etc.

34. Filling in Details.—Having completed the property map in any of the preceding ways, it will be necessary to fill in the details, and of these the only one of prime importance is the streams, for along them the coal will outcrop, up them the railroad will be built, and on them the property will be opened. Where the boundary of any property is a stream the map as made establishes so much of it. When the stream crosses a property line, its distance from any corner on that line can be determined by pacing and another point on it located. Between property lines, if the distance is not too great, say 1,000 feet, and the stream not too crooked, it can be sketched in by estimating the angles made by the stream and the division fence, or these may be determined by the compass. When the distance is too great to permit of satisfactory sketching, the stream may be traversed by compass and pacing. Small branch streams should be located when they cut out the crop.

No attempt should be made to follow all the minor bends of a stream, only those that determine its general direction being necessary.

It is advisable to pace or estimate the distance from the stream to the foot of the hill on either side in order to determine the width of the bottom lands, that is, the amount of space available for tracks and plant. An estimate should also be made of the amount of rise from the stream to the foot of the hill, and the character of the bottom lands, whether swampy, sandy, or rocky, should be noted.

PROSPECTING FOR COAL

35. General Geological Considerations.—The work required of the prospector that may strictly be classed as geological is limited to defining and mapping the coal measures and their contained coal seams, noting the dips by which the anticlines and synclines are located, and tracing faults, and the like. In properties of ordinary size, a map showing all its geological formations, strata, and coal seams is never required, the workable beds being selected for investigation and their outcrop alone mapped. With larger properties, more detail is required than with smaller ones, and when entire regions are to be investigated, a complete geological map showing all the formations may be needed.

36. Geological Maps.—Where large areas (several hundred or more square miles) are to be covered, individual seams are not mapped, but preferably the various subdivisions of the Carboniferous or other coal-bearing period. After the various groups or measures are mapped as a whole, any one series may be taken up for separate study and the seams in it mapped, but on a larger scale. The geological work demanded in disturbed and faulted regions is very complex, requiring accurate maps, and is the work of the geologist and not of the prospector.

EVIDENCES OF COAL

37. The presence of coal may be known by surface evidences, such as coal blossom, smut, float, terraces, etc., or by deduction from geological study of the region.

38. Coal Blossom, Smut, Float.—Coal is so intensely black and so universally accompanied by an overlying dark almost black shale and an underlying fireclay that in regions where it exists above water level, some trace will generally be found. This trace is usually in the form of a black smut (a mixture of coal and clay), or stain noticeable on a hill-side, on the bank of a stream, in the gully produced by a recent heavy rain, or in the road or trail over which the prospector is traveling. Pieces of coal may sometimes be found adhering to the roots of overturned trees or in the burrowings of animals and insects. Small fragments of coal or roof slate may be found in the bed of the stream, which should be followed to find the point above which these pieces do not occur. This will give a location on or near the crop; the seam may of course be above, but cannot be below. The banks of the stream should be examined for a blossom and the bottom for roof shales. When either are found a little work with the shovel may uncover the seam. If not, the examination should be continued up the bank to find a point from which the particles found in the stream are derived. When this is determined, shafting and drilling will uncover the seam.

39. Coal Terrace.—As previously explained, owing to the varying hardness of the rocks, coal seams may usually be recognized by a more or less distinct terrace or bench. Other strata of course form benches, but where the measures are flat, if the foot of a terrace is marked by a series of springs or swampy places, and particularly if the springs form a deposit of iron ore or the swamps show red slimes, the presence of coal is reasonably assured, enough so in any event to warrant more careful investigation. The iron ore and slimes result from the decomposition of the pyrites in

the seam and the subsequent solution and redeposition of the iron ore by the carbonic acid in the water. Highly pitching seams do not afford so pronounced a terrace as flat ones, a vertical seam perhaps showing as a depression between two sandstones, similar to a road between stone walls.

The coal terrace, even of the same seam on the same property, is rarely uniform in appearance. If the overlying rock varies in hardness or sensibly changes in thickness, the bench may vary from a marked concavity to a plane surface; that is, it will disappear. The breadth of the bench is also affected by the thickness of the seam, its dip, and the slope of the ground. Under the same conditions a thick seam shows a plainer bench than a thin one; a bed dipping into the hill makes a broader bench than one dipping with it, and, in a flat country, the benches are wider and more pronounced than where the hillsides are steep.

40. Vegetation as an Evidence of Coal.—The not uncommon belief that a coal seam is marked by vegetation peculiar to it is incorrect. While it is true that water-loving species may predominate on or near the springs marking the crop, or those forms of vegetable life thriving best in calciferous soil may be most numerous along a limestone ledge under the coal, yet these species will follow any line of springs or any ledge of limestone, and so are no guide to the existence of coal. However, if it is shown that certain species of trees or plants favor a certain strata at a fixed distance above or below a coal seam, this fact may be used in subsequent work to approximately locate the crop. Coal seams are rarely so thick as to have any effect in themselves on the surface vegetation.

OUTCROPPING OF COAL

41. In flat seams, the lines of outcrop are usually found along the valleys not far from the watercourses, but where the seams pitch more or less parallel with the slope of the hill, the outcrops may occur far up along the mountain flank and no evidence of the existence of coal be given in the

valley below. Where the seams dip into the hill, the outcrop is to be looked for anywhere from the foot to the summit. Where the overlying sandstone is very hard and the coal and roof shale soft, the latter often weather away into a loose mass, leaving the sandstone projecting 4 or 5 feet, like the eaves of a house. In places like this a little work with a pick and shovel under the ledge will frequently disclose the regular coal smut.

It sometimes happens that the outcrops that would ordinarily show are covered by a heavy surface wash due to glacial or other action, so that even a fairly careful examination of the region fails to bring to light any direct evidence of coal. This, however, is very rare, and care and patience will, in the vast majority of cases, discover in the roots of a fallen tree, in the sand of an ant hill, or in the washings of a stream, some small particle of coal that may be traced to the parent bed.

Where all direct indications fail, recourse must be had to the geological evidence afforded by the rocks that are exposed. If a careful study shows that these belong to the Carboniferous or other coal-bearing formation, coal is probably present in the neighborhood. If the rocks are of

FIG. 10

later age than the Carboniferous, coal may be found below by drilling through the younger rocks. An exception, however, would be the case shown in Fig. 10, where the overlying Tertiary rocks were deposited on the upturned and eroded edges of the Devonian and earlier rocks. On the other hand, if the surface rocks are older than the

Carboniferous, coal is not present unless in very exceptional cases, where the measures have been completely overturned, in which event the coal seams would be found in the hills, presumably outcropping.

LOCATING THE SEAM AND TRACING THE OUTCROP

42. After the physical or geological examination has satisfied the prospector that coal is present, procedure will vary, but in all instances the result desired is the uncovering of the seam at a sufficient number of points to satisfactorily test its continuity, quality, and thickness.

43. Deep Seams.—Where the coal exists at a depth of 100 or more feet, it can most easily, rapidly, and cheaply be explored by the use of some one of the systems of drilling, the diamond drill being preferred because it furnishes a core or section of the seam. As drilling deep properties, commonly called shaft properties, is undertaken as much to determine the depth below the surface, and consequent dip of the seam, as to test its quality, the proper location of drill holes will be discussed later.

When satisfied that the seam is only a short distance down, or when drilling machinery is not available, a prospect shaft may be sunk to reach the coal.

44. Prospecting Shafts.—Some prefer square shafts, others prefer round, but if the ground is firm, the shape is a matter of minor consideration. A rectangular shaft about 4 feet by 5 feet gives sufficient working room, and is, for some reasons, preferable to any other form, as it is easily timbered and is therefore particularly adapted to sinking in loose, treacherous ground that threatens to cave in and needs heavy timbering.

Good laborers will sometimes sink a shaft 10 feet deep without a staging or platform to throw the dirt on. When the depth exceeds 10 feet, it is necessary to build a staging or cut a step to throw the earth on, from which it is again

shoveled and thrown from the pit, or to erect a windlass or tripod for hoisting.

When the depth exceeds 15 or 18 feet, a windlass or tripod becomes necessary. The windlass may be a very primitive affair, but should be strongly built. A hemp rope 1 inch in diameter and a strong, iron-bound wooden bucket holding about 80 or 100 pounds complete the outfit. A tripod is simply a three-legged support bearing a pulley, through which the hoisting rope runs, but is very useful in a mountainous country, where it is difficult to carry a windlass.

The timber sets are either supported from beneath or hung from above, and in either case are wedged in place as tightly as possible by a series of boards, waste slabs, or small round pieces driven in between the timbers and the sides.

The distance between each set of timbers depends on the character of the ground and depth to which timbering is necessary. It is never advisable to place them more than 6 feet apart, and generally they should be closer together.

Round timbers, 6 or 8 inches thick, may be used for the crib work, but square timbers are better, as they can be more easily and accurately fitted.

One end, side, corner, or the center of the pit is kept in advance of the average level of the shaft bottom, thus providing a sump for the water, as well as giving a loose end to the material being excavated.

45. Outcropping Seams.—With seams above water level, the methods followed will be modified by the topography of the country and by the presence or absence of existing openings. Three cases will be considered under this head: (1) where the seam has already been more or less opened up by country banks; (2) where no openings have been yet made on the coal, but where the outcrop is covered by only a thin covering of soil; (3) where the entire surface is covered by a thick deposit of drift. The simplest case will be considered first.

1. *Where the Seam Has Been Opened.*—Where a sufficient number of openings exist to show the character of the seam,

the work of the prospector will generally be limited to tracing the crop from opening to opening to make sure that the seam is continuous and that too much has not been cut out by ravines or removed on flat hillsides by erosive agencies. As noted above, a bench is the usual accompaniment of coal seams, but on some portions of nearly all properties the bench is not plainly marked. If the distance of the seam above or below a stratum of sandstone, limestone, or other hard rock is known, and this stratum has been identified on another portion of the property where the bench is wanting, the approximate location of the latter may be made by the barometer or the hand level.

If only the location of the coal is desired, and not an inspection of the seam, it may be drilled to with a jumper drill, or an earth auger, care being taken to start above where the seam is supposed to be; that is, if the levels call for the coal 60 feet below the sandstone, start the drilling at 55 feet or even 50 feet. If the coal is not found at the right depth, it shows that it has been removed by erosion, and another hole should be put down farther back. Frequently, a little work with the pick and shovel will show some trace of coal that can be followed up by a narrow prospect trench driven at right angles to the assumed crop line. If the surface covering is thick, it would be better to go farther back on the crop and sink a trial shaft to find the coal, provided a section of the seam and samples for analysis are desired.

It is frequently possible to locate the crop when lost, by standing on the opposite hillside and sighting from one known bench or opening to another, locating by the eye a desired point between. This is a good way to trace a seam across a valley, but after tracing and finding it, unless sure of its identity with the distant seam, it is well to uncover the rocks both above and below, noting their similarity. Care must be taken not to confound coal and black shale. The latter is frequently found highly impregnated with carbonaceous matter, forming a blossom strikingly similar to coal. With highly pitching seams the straight or curved furrow made by the crop line may be followed between openings, but if no

furrow or other mark exists, the seam may be located in reasonably flat countries by its horizontal distance from some easily recognized outcropping rock and opened by a shallow shaft where necessary.

2. *Where No Openings Have Been Made.*—In previously unexplored regions, where the topography of the country is marked by steep hillsides little covered with soil, much economy of time and labor will result if, instead of trying to uncover the seam at the first blossom noted, a narrow trench is dug from the top to the bottom of the hill down to the solid rock. If properly located, one trench will uncover all the rocks and seams above water level on the property. A geological section can be made, specimens of the rocks for comparison taken, the thickness of the various rocks and seams measured, and their distance apart noted by the barometer, all of which will serve as a basis for locating or identifying seams in other portions of the property. For very large properties, two of these hillside sections may be needed. Any seam thus uncovered that appears of desirable thickness and quality can be drifted on to any distance necessary.

FIG. 11

The section shown in Fig. 11 is abridged from the Second Geological Survey of Pennsylvania. The elevations as obtained by the barometer are given in the right-hand column for the base of each coal seam. It will be noted that these do not agree with the height above the river, as deduced from the thicknesses of the rocks. This is to be expected owing to the inaccuracy of the barometer and the difficulty in measuring the thickness

of the rocks. When the seams are pitching, and outcrop, a trench may be dug at right angles to the line of strike down to the rock as before, and any seams of desirable appearance further prospected by slope or shaft directly on the coal. A section is also desirable in this case for comparison with other sections obtained elsewhere on the property. In the case shown by Fig. 11, the seams were horizontal or nearly so and the distance between them determined by direct vertical measurement.

In Fig. 12 the distances are measured horizontally and

FIG. 12

the true distance between the seams perpendicular to the plane of stratification is determined by formula

$$\text{perpendicular distance} = \text{horizontal distance} \times \sin \text{ of angle of dip}$$

or, in the case in Fig. 12, the vertical distance from A to B, the dip being 56° and the horizontal distance 125 feet, is $Ba = 125 \text{ feet} \times \sin 56° = 125 \times .829 = 104$ feet. The vertical distance apart of the other seams may be worked out in the same way. Where the seams have but a slight dip and their outcrops are some distance horizontally apart, it is not usual for the dips of both to be the same, one being nearer the synclinal and hence flatter than the other. In this case the average of the dips of the two seams may be taken. Absolute accuracy in these sections is not obtainable, nor is it necessary; 1 foot or even 5 feet of error makes practically no difference. The dip should be taken on the floor of the seam, so that no errors are brought in by false bedding and the like. A convenient rule and one fairly accurate for dips up to 45° is the following: "If the breadth of inclined strata outcropping on level ground be measured across their crop at right angles to the strike of the strata, their true thickness will be equal to $\frac{1}{12}$ of such

breadth of crop for each 5° of the dip of the seam. O may be put thus: Divide the angle of dip by 60, and mu ply the result obtained by the breadth of crop; the prod is the thickness of the seam. Thus, by the first rule, s pose a mass of strata measures across the strike 1,200 f and is uniformly inclined at an angle of 5°; its real th ness will be $\frac{1}{12}$ of 1,200, or 100 feet. At 10° the thickn will be $\frac{2}{12}$, or $\frac{1}{6}$, of 1,200, or 200 feet; at 15° it will be $\frac{3}{12}$ $\frac{1}{4}$, of 1,200, or 300 feet; at 20°, $\frac{1}{3}$, or 400 feet." Or, ag suppose the horizontal distance between two seams, e dipping 35°, is 120 feet, the perpendicular distance of th seams apart, by rule, would be

$$\text{Distance apart} = \tfrac{35}{60} \times 120 = 70 \text{ feet.}$$

By the more accurate rule first given,

$$\begin{aligned}\text{perpendicular distance} &= 120 \times \sin 35° \\ &= 120 \times .5736 = 68.8 \text{ feet.}\end{aligned}$$

The student should note that the elaborate sections m up of the conventional signs for the various compor rocks are not used or made in the field. The field sec merely states in words the kind and distance apart of rocks and their contained coal seams; the illustrated sec being left for the final report on the property.

3. *Where the Surface Is Covered by Drift.*—Where country is generally flat and covered by a more or less he surface deposit or wash, follow up the most pronour blossom, and endeavor to locate the parent bed. Somewh in the neighborhood, outcropping rocks will be found, sh ing whether we are dealing with a region composed of c paratively horizontal or of highly inclined strata. If presence of coal is indicated by small particles adherin the roots of overturned trees or mingled with soil thrown animals in their burrowing, the seam cannot be much be where these are found. It may be above, and the tra washed down by rains, being subsequently brought to li by the work of the animals, or the seam may be actually the place where its fragments are found. In the latter ca

a little digging will bring to light a decided blossom and a shallow shaft will expose the coal. If a few hours' work leads to no definite results, a hole should be sunk with a jumper drill or earth auger from the bottom of the shaft already made. If the hole passes through rock without yielding coal, the seam is probably above, and the search for further traces should be continued at a higher level, until certain that we have reached a point above which no particles of coal may be found. At this point the shovel and drill must again be resorted to. When finally located, the trial shaft should be sunk to the floor of the coal, and this in turn drifted on, or if pitching, opened by a slope or shaft, to obtain sections and samples and to measure the direction and amount of the dip. If the seam is horizontal or rises with the hill, if the country is not too flat nor the cover too thick, and the appearance of the seam at the foot of the shaft or the thickness as shown by the drill warrants increased expense, it is well to go down the slope, as shown in Fig. 13, to a point sufficiently below the seam to insure drainage, and start an open cut to reach the bed. This permits of draining and much easier inspection.

Fig. 13 illustrates a case where particles of roof slate and coal were found on the roots of a fallen tree a short distance below *a*. The trial shaft was started above the tree to

FIG. 13

insure, if possible, a good roof to the seam when found. At 5 feet the presence of decomposed roof slate was noted, digging stopped, and a drill hole put down that passed into the

but when the bed dips with the hill, the crop is not in quently turned over and a prospect shaft (see *b*, Fig. would give a very erroneous idea of the true thickness of seam. All shafts, particularly in pitching seams, shoulc continued until the floor and roof are both uncovered the measurements for thickness taken at right angles to dip. If the seam is very thick, or stands nearly vertica level should be driven each way from the foot of the sl until the roof and floor are reached.

48. Effect of Faults on Outcrop.—The effect of fa on the outcrop is marked. If the plane of the fault is ı allel to the line of dip in pitching seams, the crop is shaı cut off; but if parallel to the strike of the seam, it has effect on the crop line, though of course breaking the c tinuity of the seam at whatever depth below the surface fault cuts the bed. With horizontal or greatly slop seams, both dip and strike faults cut out the bed and n usually be traced by the vertical displacement of the c crop. Where after the formation of a fault the surface been deeply eroded, an apparent duplication of seam: brought about.

IDENTIFYING SEAMS

49. By identification of seams is meant the recognit of the same seam at more or less widely separated pla(Long practice will enable the prospector to determine : given seam by what may be called intuition; that is, soı thing in the appearance of the coal convinces him, reasons that he can rarely explain, that the opening un examination is on No. 8 or No. 9, or the Upper Freeporl Middle Kittanning, etc., as may be.

All seams have general characteristics serving to iden' them under usual or normal conditions, but frequently, : especially in dealing with openings far apart, the norı characteristics are modified by local conditions. Whai there to identify a seam 5 feet 6 inches thick, more or l

which may then be reached by shaft at *e* or by extending the open cut at *d*, as explained previously.

When the coal has been found, its distance above or below some outcropping rock should be noted, the distance serving as a measuring rod for its location elsewhere. In the above cases, where an open cut is used, if the prospector is satisfied he is on the horizon of the coal, before going too far, he should come back along the cut and widen it sufficiently to permit the use of a wheelbarrow.

47. Misplaced Outcrops.—It usually happens that the cut started on the crop shows the blossom running up, due to the creep of the surface down the hill. In some cases a strong blossom will be cut off by a bed of clay or appears to be suddenly replaced by that substance. This is evidence of

FIG. 15

a slip or breaking away of a portion of the blossom from the main body, the severed portion sliding down hill. All that can be done is to start a new trench higher up the hill, or, if possible, use the jumper to locate the true blossom or seam.

Occasionally, it happens that whole sections of the hill have slipped bodily to a lower level, and in these cases, unless a drift several yards in length has been driven on the seam and its continuity proved, the levels run to determine the dip may be seriously in error. The creep, or slip, of the blossom or the coal itself down the hill when the seams are horizontal or dipping into the hill will not give an exaggerated idea as to the thickness of the seam (see *a*, Fig. 15);

but when the bed dips with the hill, the crop is not infrequently turned over and a prospect shaft (see *b*, Fig. 1l would give a very erroneous idea of the true thickness of th seam. All shafts, particularly in pitching seams, should t continued until the floor and roof are both uncovered an the measurements for thickness taken at right angles to tl dip. If the seam is very thick, or stands nearly vertical, level should be driven each way from the foot of the sha until the roof and floor are reached.

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IDENTIFYING SEAMS

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blocky, with another 3 feet 2 inches thick, having a tendency to break into long prisms at right angles to the bedding?

If two seams 1 mile apart have the same thickness and texture, they are probably the same, which would be confirmed if each had the same impurity in the same place; for example, 2 inches of slate 8 inches from the floor. Two seams of similar texture 8 or 10 miles apart are probably the same if one is 3 feet thick and has 1 inch of slate 6 inches above the floor, and the other is 3 feet 9 inches thick and has a 4-inch slate 9 inches up. Confirmation would be afforded if each were 30 feet below a heavy sandstone 20 feet thick and 18 feet above a 2-foot coal seam. Two seams 30 or more miles apart, with more or less dissimilar texture, impurities, and thickness, are probably identical when one is 30 feet below a massive sandstone 20 feet thick and 18 feet above a 2-foot coal seam, and the other is 40 feet below a coarse conglomerate 15 feet thick and 25 feet above an 18-inch coal seam. This, again, will be confirmed if the rocks immediately overlying and underlying each seam are similar or identical; for example, if the regular fireclay floor in each case is underlain with 2 feet of limestone.

50. The point to be emphasized is that the farther apart the two seams to be identified are, the more points must they have in common to render the identification complete. It is not to be expected, nor is it necessary for purposes of identification, that the same distance apart of seams or rocks be preserved over wide areas. Relative thickness and position will usually prevail, while absolute thickness and position will vary; thus, in going southwest from Pennsylvania into West Virginia, the coal measures thicken, and, while the seams are absolutely farther apart in the latter State, yet their relative distance apart is practically the same. With seams 100 or more miles apart, it may be necessary to uncover all the rocks for a long distance both above and below each seam, and perhaps make some study of the fossil remains in order to identify and correlate the two sections.

The student may consult Bulletin No. 65 of the Unite States Geological Survey, by I. C. White, in which th various coal seams of Pennsylvania, West Virginia, an Eastern Ohio are correlated and sections given of the sam formations many hundreds of miles apart. A study of thi pamphlet will show how and why the measures are identi fied in regions where horizontal strata prevail.

When we come to take up the identification of pitchin seams probably broken by faults and occurring in mountai ous regions, where disturbed and contorted strata abound the problem is one of extreme difficulty. In fact, the sol tion of these complicated "pieces of ground" should be le for the highly trained geologist; it is not expected of prospector.

The anthracite fields of the United States and the co measures of France and England were developed witho any foreknowledge as to the geological difficulties to be m in the near future. Perhaps it is as well that this know edge was lacking, or the seams might otherwise never ha been opened. All the prospector can do is to follow t more obvious irregularities as displayed on the surface a detect the more pronounced underground disturbances drilling, leaving the minor features and even many of t larger ones to be brought to light as the mining of the c progresses.

51. Relative Position of Coal Seams.—By this meant whether a seam is higher or lower in the local ser than another in the immediate neighborhood. Fig.

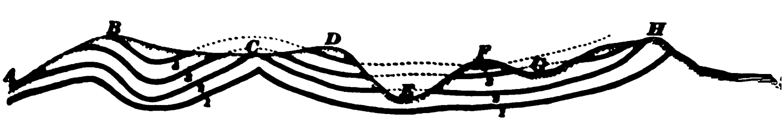

FIG. 16

shows the various ways seams may occur in a region not highly disturbed. When this region is entered from the side A, the seams as passed over in ascending the mountain

to *B* will be in their true sequence; that is, the oldest will be found in the valley at *A* and the youngest on the summit at *B*. This is true in every case in the figure except when going from *G* to *H*, or when the country is approached from *I*, in descending the slope from *H* to *G*. Here the older seam *2* is met with much higher on the hill than the younger *3*, which is passed over twice before the valley is reached. This occurrence is so common in passing from the summit of a high anticlinal ridge to the valley below as to be worthy of especial attention, and the student must bear in mind that in many cases the highest seam geographically is the lowest geologically. Aside from this one exception, in comparatively undisturbed regions, the seams as met are in their natural order, that is, in going up a hill we pass from lower to higher. Fig. 17 illustrates some of the cases

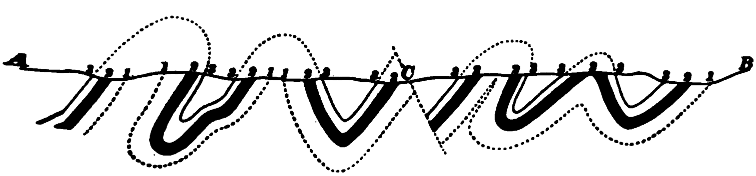

FIG. 17

met with in contorted and faulted seams. When it is remembered that the ground is usually covered with more or less wash, concealing all but a few of the outcrops, the difficulty in determining the relative age of the various seams will be appreciated. The appearance of the outcrop is modified by the dip of the anticlines and the topography of the surface, instances arising where the youngest seam outcrops highest in the hills. The selection of some stratum of sandstone or slate as a *basal* rock on which to build a section from which the relative age of the beds is determined is made difficult, because in disturbed regions the thickness, color, and physical characteristics of rocks will vary widely in short distances.

In the case shown in Fig. 17, where two seams *1* and *3* are similar in thickness, and one *2* is much larger, efforts should

be made to unravel the foldings of the larger and determin its roof and floor. If this can be done, this problem i solved so far as the age of the beds is concerned, becaus all seams above the roof must be younger and all below the floor older than *2*. But the determination of the roof and floor is not always a simple matter. To quote from Mr. H. M. Chance. "The occurrence of stigmariæ in one of the rock walls of the seam is presumptive evidence that the stratum containing them is the floor of the seam, but if sigillariæ, fern leaves, etc. are found, the rock is probably the roof or top rock, although both of these fossil plant remains may occur in either the roof or floor of a coal seam." In a complicated piece of ground, such as that shown in Fig. 17, the relative age of the beds is only of importance in so far as this knowledge may help in solving the more important problem of their irregularities.

MAPPING THE CROP

52. Flat Seams.—The same general methods pursued in mapping the streams may be followed with the crop line. Any openings or other points on it should be located with the compass and by pacing from some established point on the stream or from some property corner. When the crop leaves the stream and runs back into the hills, a rapid traverse will be necessary, unless the property is cut up into comparatively small farms (100 acres or so), when the method of locating from corners by cross-fences will serve.

In Fig. 7, two seams are shown 60 feet apart. On the Garrett, Holt, and Hall properties the hills were so steep that on the small scale of the map the seams appear superimposed. Openings Nos. *1*, *2*, and *3* are on the lower seam. The bench of each seam was plain, from No. *7* opening on the upper to the division line between the Smith and Hays farms. From there on the seams were located with a jumper drill at several points. The seven openings and the holes made with the jumper were located by short traverses

from the nearest corner, and the intersection of the bench and property line determined by pacing along the fences. The coal showed in the run at *U* and *U'* and on the I. W. Hall tract; a heavy sandstone 10 feet above the lower coal located the crop.

In dealing with large properties, such as are shown in Fig. 9, the crop must be sketched in as above, except that we have no fence (property) lines as a guide. Prominent bends in the main stream, fords, junctions of branch streams, intersections of wagon roads, or any artificial objects, such as railroad bridges, churches, houses, and the like, shown on the topographic sheets, must be used as base points from which to start short traverses to the crop.

Where a number of seams outcrops on a property, unless the ground is very flat, they may be located at the same time by estimating their horizontal distance apart, care being taken to have a different symbol for each crop. When the hillsides are steep, the seams near together, and the scale of the map small, the crops will practically coincide on the map. In this case it is better not to attempt to distinguish between them; merely note their vertical and horizontal distances apart. Both the above cases are shown in Fig. 7.

Where triangulation has been used, the triangulation points may be made bases for further triangulation to points on the crop, or for traverses thereto.

53. Pitching Seams.—With pitching seams the simple methods outlined above will hardly suffice, because the outcrops are apt to be far from the streams. In dealing with these, the transit and stadia should be used because of the long sights possible. This method is fully as rapid as a compass survey and far more accurate. In fact, if it is necessary to work out the geological structure of the region, the more accurate the map is the better.

54. Outcrop Maps.—If the property is to be developed, and if the coal seam is outcropping, or if the seam is below water level, some rock stratum at a known distance above

the coal and known as the *guide rock* should be accurately mapped and the elevations of the crop taken every 250 or 500 feet. This map should accurately show the anticlines and synclines occurring on the property, and it will be useful in locating the openings for the development of the field. The elevation and direction and amount of dip of all outcrops should be taken. The elevations are preferably taken with the Y level; otherwise by the double barometer system. The occurrence of anticlines and synclines should be noted. If a cross-section of the measures is desired, a few elevations on the tops of the ridges and along the streams are measured as near the proposed section line as possible, so that a fairly accurate profile of the surface may be had.

Fig. 18 shows the map of a coal seam or guide rock outcropping on both sides of the two streams. The figures along

FIG. 18

the crop give the elevation above the sea level, and the arrows the direction of dip. Exposures were noted and

elevations taken by the double barometer method at the points indicated by the arrows and figures. At *B* the synclinal could be seen in the folds of the seam, and at *A* in those of a rock at a known distance below the bed, the elevation of the seam at this point being deduced from that of the rock. Since the dips on the two sides of the left-hand stream are in opposite directions, there must be an anticline between the crop lines approximately parallel to the line *A B*. It will be noticed that no elevations were necessary to determine the syncline, the direction of the dip answering all purposes. Likewise, the coal seam need not have been opened, because the direction of the dip determined from the exposure of any rock above or below the coal would have been the same as that of the bed itself. Finally, the syncline as determined by the surface exposures will correspond to that in a seam below water level. The coal seam in the central coal area should be opened at *C*, so that all the workings will be to the rise; the west area by an opening near *D*, as far up the stream as possible, in order to get *behind* the dip; that in the east area by a rise heading to the southeast, when all the workings would be to the left of the entry and to the rise.

55. Columnar Sections.—A **columnar section** similar to that shown in Fig. 6, shows the vertical arrangement of the strata. While it is desirable to show all the rocks in the section, it usually suffices to note the coal seams and only those rocks whose outcrop occurs naturally or can readily be exposed. Where knowledge of any particular stratum is wanting, the place in the section where it belongs is left blank and the word "concealed" written opposite in the column giving the names of the formation.

A long columnar section may be made up of two portions, the one above water level, the other below. The portion above water may be taken from a hillside trench, and if that below water cannot be obtained by measurement of the distance between outcrops, the underground record may be gotten by the drill and joined to the surface exposure noted in the trench.

56. Cross-Sections. — A **cross-section** shows the arrangement of the rocks, not only vertically, but horizontally as well. It consists of a series of vertical sections placed side by side in a plane perpendicular to the strike, and gives a view of the strata similar to that had in a railroad cut. It is used in reports to illustrate the extent of the measures in a basin, or to unravel the structure of a complicated piece of ground where the map or ground plan does not suffice, or to help solve problems in haulage and the like. The plane of the section should be taken parallel

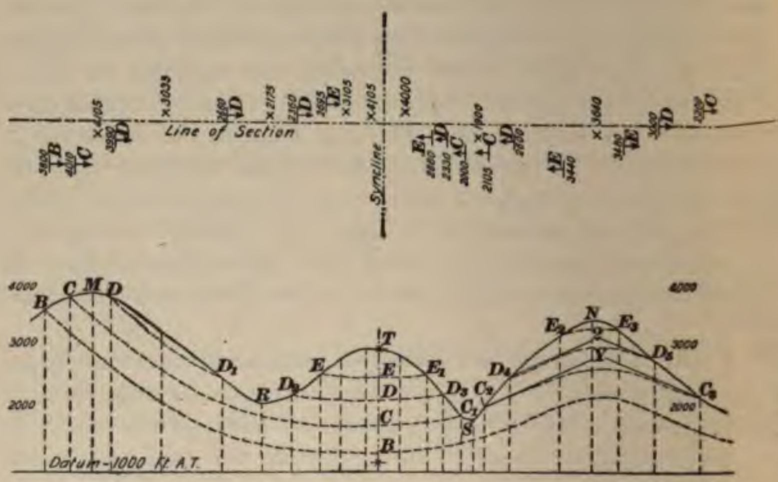

FIG. 19

to the dip, or at right angles to the strike or anticlines, and midway between the exposures of the various strata whose dips and elevations have been determined in the field. When the place for an observation is not directly on the line of section, it is projected into the plane of section by moving it horizontally along the line of strike. The simplest case would be that shown in Fig. 19, in which the upper portion represents a horizontal plat of the notes as taken in the field, and the lower portion the cross-section as

made from the field notes. The horizontal and vertical scales are the same.

The horizontal plat shows the crops of the various beds with a letter attached to distinguish between them. The elevation, and the direction of dip, but not the amount, are given in each instance, as well as a few surface elevations at points marked x.

57. To construct such a cross-section, first draw a horizontal line to represent a datum of known elevation. In this instance, since all the elevations are over 1,000 feet, our datum may be taken as this distance above sea level. Next project the observations when necessary into the plane of the section by drawing a line at right angles to the section line through the place where any observation was made. Where this line crosses the section line, the place of observation is located horizontally in the plane of the section. Along the datum line, and on some convenient scale, lay off the above distances and erect a series of perpendiculars. On these perpendiculars mark the elevations as taken from the horizonal plat, less the height of the datum above sea level. In the above case, 1,000 feet would be deducted from each measurement. Next sketch in the profile of the surface M–R–T–S–N and erect a perpendicular to the datum line where the synclinal axis crosses the section line. We will then have a profile of the surface on which are located the outcrops of the seams at their proper elevation. The various strata must next be drawn in, and here procedure varies.

If it be assumed that the beds are straight between exposures, points of outcrop such as D–D_1, D_2–D_3 should be joined by straight lines. These lines, if prolonged to intersection, would form a more or less acute V, and show a thickening of the strata at the apex of the V. The better plan is to draw in the strata as if they were a series of parallel compound curves approximately tangent to the dip at each point of outcrop. This preserves their uniform thickness throughout. Thus, in dealing with the D seam, Fig. 19,

try to find a curve that will intersect the points of outcrop D–D_1–D_2–D_3–D_4. When this is located satisfactorily, the other beds B–C–E may be drawn in parallel thereto. If a bore hole has been sunk in either valley at R or S, the points where it intersects the beds C and D may be located on a perpendicular to the datum line erected for this purpose. The deepest portion of the basin is, of course, along the line of the synclinal axis. In dealing with the anticline forming the hill N, a knowledge of the amount of dip, as well as the direction, will be necessary. For the D and C seams the lines representing the dip should be prolonged until they intersect at 2 and Y, when curves conformable to the curves D–D_1–D_2–D_3–D_4 and C–C_1–C_2, respectively, may be drawn tangent to the line of dip, joining D_4–D_5 and C_2–C_3. The other strata are, of course, sketched in parallel to C and D.

It will be noted that the cross-section is exact only at the points of exposure of the seams; everywhere else it is an approximation, because of the uncertainty of our knowledge as to underground conditions.

Sections such as the above serve to embellish a report and throw considerable light on underground structure, but in no sense are they as exact as the map from which they are made. Much depends on the judgment and skill of the prospector, and every available surface feature should be mapped before the cross-section is attempted.

In Fig. 19, had the amounts of all the dips been taken, these might have been laid off at D–D_1–D_2–D_3, as well as at D_4–D_5, and produced until they intersected as at 2. This would have given a series of tangents, to fit which a compound curve could be selected, but it is problematical if better results would be obtained than by the first method, where the curves are sketched in to conform as nearly as possible to observed conditions.

58. Geological Field Sketch.—Fig. 20 shows the field sketch for a more complete geological map, and Fig. 21 the completed map of the same.


1760′
1760′
1740′
1720
1710′
1690′
1650′
1680′
1700′
1760′
1800′
1840′
1860′
FAULT
FAULT
FAULT
N

FIG. 20


C
A
E
FAULT
N
B
D

FIG. 21

Fig. 22 shows two cross-sections made through t
strata mapped in Fig. 21. That these sections do r

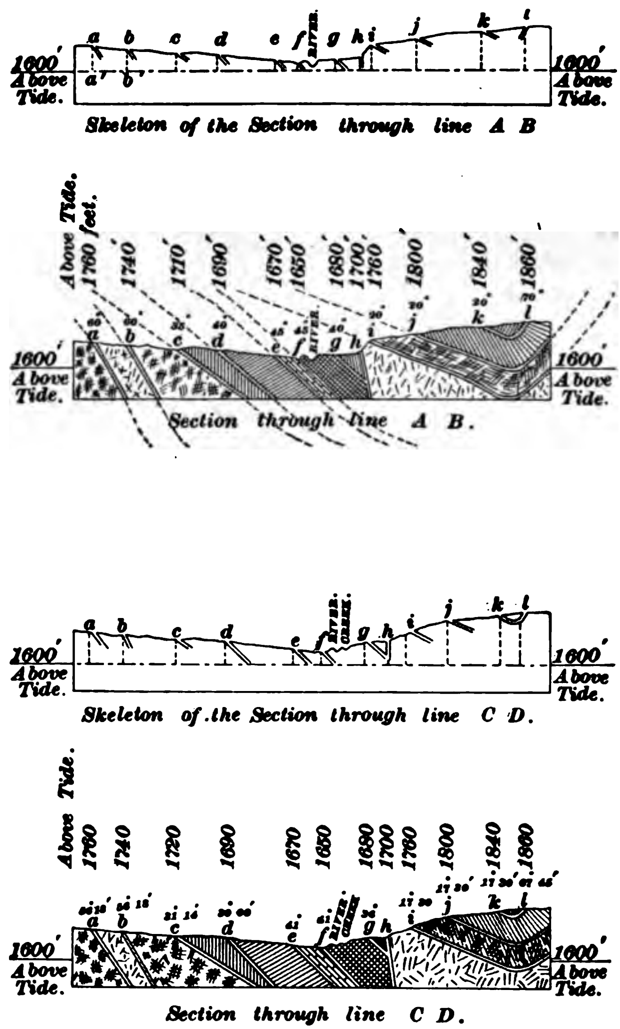

FIG. 22

show the true condition of affairs is probable, being made
prolonging the lines of dip in the same direction for the f

height of the section. That the dip would be regular for even a fraction of this distance is, of course, improbable. No satisfactory method can be devised by which the surface outcrops and dips of contorted strata may be made to show, except approximately, the conditions prevailing underground. When dealing with this class of rocks, the deductions made from surface observations should be confirmed by drilling, and even then the probable underground structure should only be penciled and not inked on the map, so that subsequent developments would not necessitate unsightly erasures.

Fig. 23, adapted from Mr. H. M. Chance, shows three seams outcropping at A–B–C–A'–B'–C', and dipping sharply but regularly toward a synclinal axis X Y, which is also inclined from X toward Y. The outcrops where observed are shown by full lines; where drawn in, by dotted lines. The plane of the section may be taken in either of two ways. In one it is drawn parallel to the dips, as P–O–R, and is consequently broken where it crosses the syncline; in the other, M–O–N, it is continuous and at right angles to a vertical plane through the syncline X Y. In either case the method of construction is the same, but the results are different. The points of observed dip are projected into the plane of the section by carrying them along the strike. Thus, in the first case, A–B–C–A'–B'–C' become a–b–c–a_2–b_2–c_2, and in the second a_1–b_1–c_1–a_2–b_2–c_2.

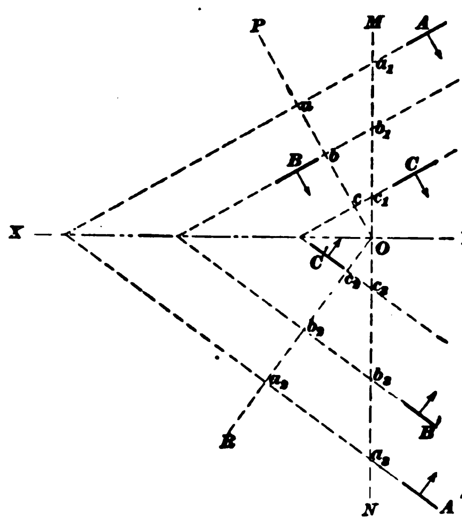

FIG. 23

A datum line corresponding to a–O–a_2 or a_1–O–a_3 is next drawn, and the distances ab, bc, cOc_2, c_2b_2, and b_2a_2, or a_1b_1, b_1c_1, c_1c_3, c_3b_3, and b_3a_3 laid off along its length and perpendiculars erected as before. On these perpendiculars are marked the elevations of the various crops, and the several dips are then laid off at these points, and the lines of dip are prolonged until they intersect on the line of the synclinal axis, giving sections such as are shown in Figs. 24 and 25, respectively. It will be observed that the true dips of the beds are preserved in each instance,

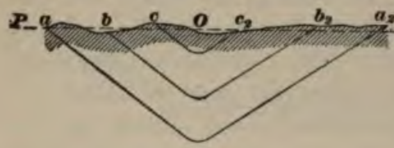

FIG. 24

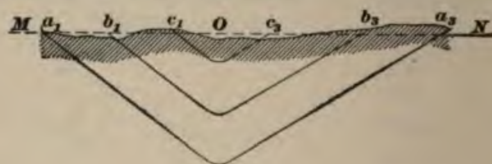

FIG. 25

but that in Fig. 25 the thickness of the strata is exaggerated, because the line $a_1 O$, Fig. 23, is longer than the line aO. The beds may be shown forming a **V**-shaped intersection, or the apexes may be rounded, as shown. The **V** shape, however, shows the probable maximum depth of the seams.

Sections such as the above, while only approximately correct, owing to probable, but unknown, changes of dip, are of value to the prospector in showing roughly what may be expected underground. The true conditions will vary from the theoretic conditions, shown in the section, but the two will more nearly conform as the strata are more regular.

In conclusion, whatever may be our deductions as to underground conditions from the examination of surface exposures, these should be confirmed by drilling. The test of the drill is final; it is desirable in undisturbed and flat regions, and is essential in dealing with contorted strata.

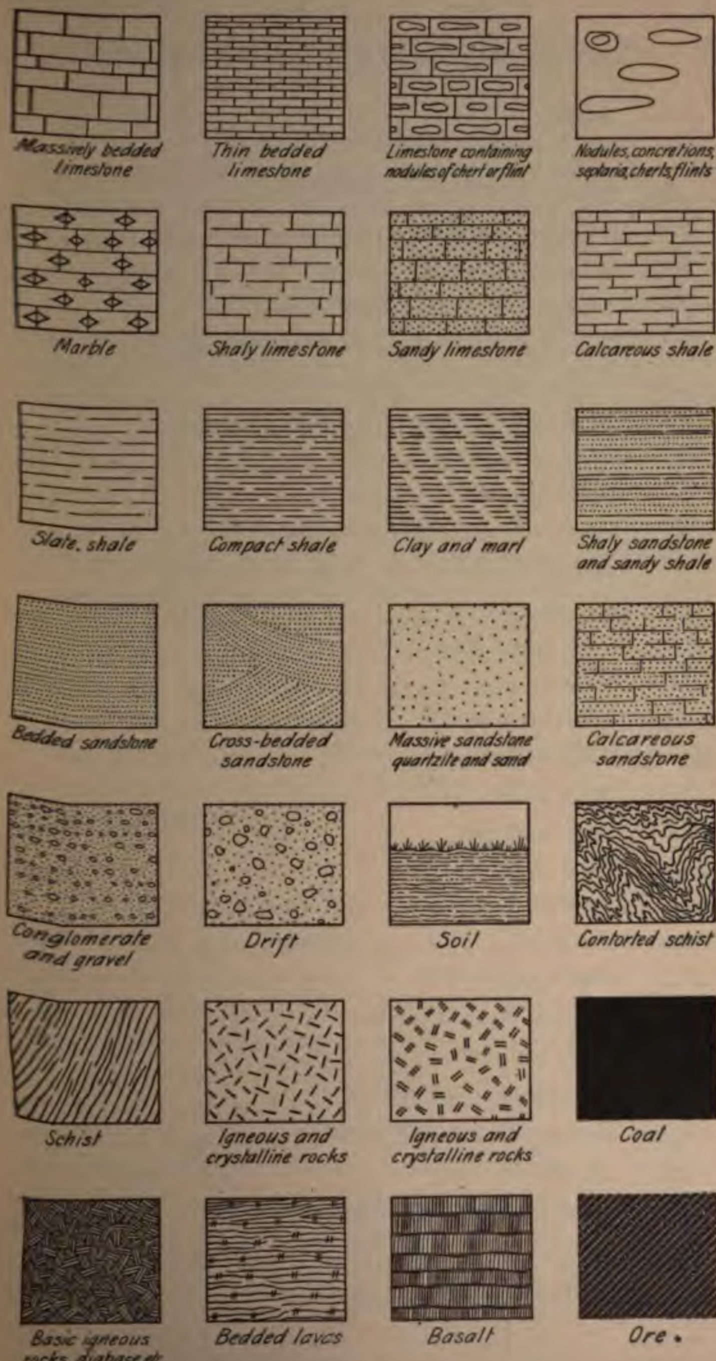
Massively bedded limestone
Thin bedded limestone
Limestone containing nodules of chert or flint
Nodules, concretions, septaria, cherts, flints
Marble
Shaly limestone
Sandy limestone
Calcareous shale
Slate, shale
Compact shale
Clay and marl
Shaly sandstone and sandy shale
Bedded sandstone
Cross-bedded sandstone
Massive sandstone quartzite and sand
Calcareous sandstone
Conglomerate and gravel
Drift
Soil
Contorted schist
Schist
Igneous and crystalline rocks
Igneous and crystalline rocks
Coal
Basic igneous rocks, diabase, etc.
Bedded lavas
Basalt
Ore.

FIG. 26

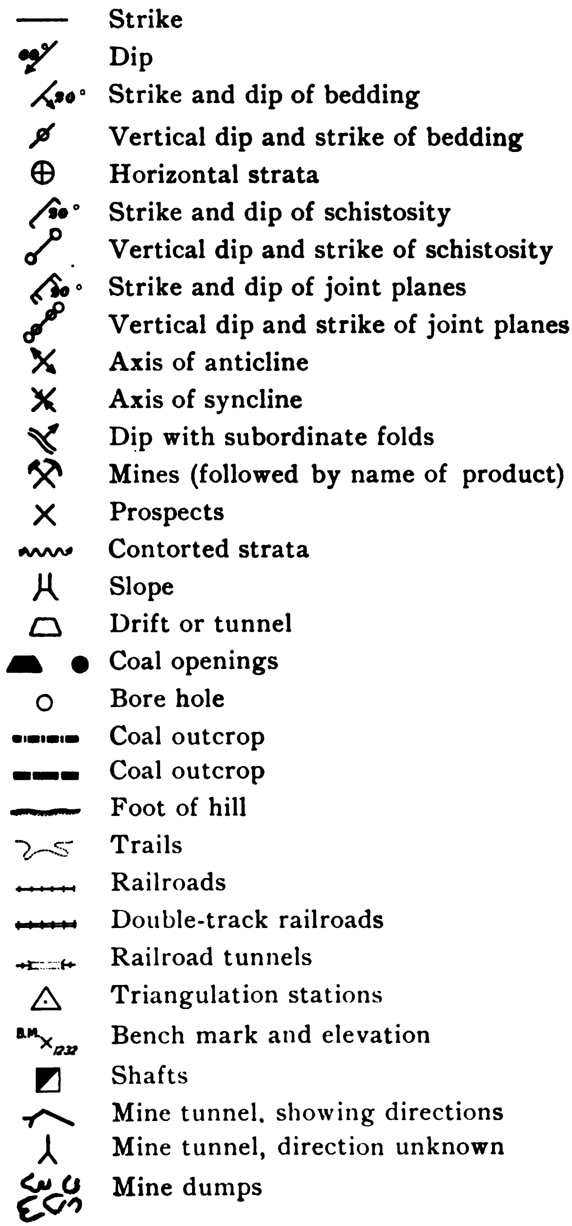
Strike
Dip
Strike and dip of bedding
Vertical dip and strike of bedding
Horizontal strata
Strike and dip of schistosity
Vertical dip and strike of schistosity
Strike and dip of joint planes
Vertical dip and strike of joint planes
Axis of anticline
Axis of syncline
Dip with subordinate folds
Mines (followed by name of product)
Prospects
Contorted strata
Slope
Drift or tunnel
Coal openings
Bore hole
Coal outcrop
Coal outcrop
Foot of hill
Trails
Railroads
Double-track railroads
Railroad tunnels
Triangulation stations
Bench mark and elevation
Shafts
Mine tunnel, showing directions
Mine tunnel, direction unknown
Mine dumps

Fig. 27

CONVENTIONAL SIGNS

59. With small scale maps, it is impossible to place thereon in the field all the notes necessary to be preserved, and some system of signs has to be formulated to replace written words. Fig. 26 shows the conventional signs as given by the United States Geological Survey, for the ordinary rock formations; they are of service in illustrating a section made down a hillside or from bore hole records.

Fig. 27 shows a number of symbols used to denote certain facts in the occurrence of the rocks or the presence of certain minerals. In practice, others than those shown may be improvised to meet any particular case.

On the very small scale maps used in "working up" large properties, it will not be possible to use many of these conventional signs, because of confusion resulting from observations taken near together. In such cases, and even when the symbols are used, it is best to mark by a number the place on the map where an observation was made, and under the corresponding number in the field book write all the data gathered at that place; in the office the data taken in the field can be placed on the larger, or detail, map with the proper signs affixed.

THE DRILL IN PROSPECTING

60. Shafting and Drilling.—If the seam nowhere outcrops on the property, or it is desired to test a seam at points back from the line of outcrop, or the depth, dip, and strike require investigation, shafting or drilling (boring) must be resorted to. Whether shafting or drilling is used is largely based on commercial considerations, such as the number and depth of shafts or holes necessary to properly prove the property. If three or four shafts 50 feet deep will suffice, it is better to sink them than to drill, for two reasons: (1) Because no drilling contractor will ship his plant into the field to drill 200 or 300 feet of holes involving three or four moves, except at an exorbitant price

per foot; (2) though the drilling is cheaper if the plant is on the ground, the advantages gained by examining the coal in a 4′ × 5′ shaft over the inspection of a 1¼-inch core are so manifest that the increased expense should be incurred; (3) shaft openings can often be utilized in the later working of the seam; (4) drifts in the seam can be run from a shaft, the top and bottom rock can be thoroughly examined and an estimate made of the probable amount of water that will be met with in the mining. On the other hand, when holes aggregating several thousand feet have to be put down, drilling must be resorted to. To be sure, shafts are always preferable, but it is safe to assume that the economic conditions making a seam at a depth of 1,000 feet valuable will not be affected by any uncertainty in our knowledge of the coal when based on the examination of a core as compared with that gained by actual inspection of the coal at the foot of a trial shaft; therefore, shafting is never undertaken with deep seams.

61. Systems of Boring or Drilling.—The two chief systems of boring or drilling are: (1) By a percussion drill, which chips the rock into small fragments, subsequently removed: this is adaptable to testing the depth of coal seams; the stationary or portable well drill is an example; (2) by a rapidly revolving ring that grinds the rock in an annular space into dust, subsequently bringing up a core or section of the formation passed through; this is adaptable to testing both the quality and depth of a coal seam; the diamond drill and the Davis calyx drill are examples.

62. Choice of System.—Where the presence or absence of coal alone is to be determined, or its depth below the surface for the purpose of calculating the dip is the point desired, the percussion system gives good results and is generally cheaper than the rotary. The rotary system is usually preferable for testing the quality of a seam, and the increased knowledge of a seam obtainable from examining the core furnished over that obtainable from the fine sludge usually brought up by the percussive system, is so apparent

as to need little explanation. Two illustrations will serve. Some seams are so largely made up of bony coal and other impurities that in appearance are like good coal, that drilling by the ordinary percussive methods gives little or no information as to thickness and quality. Again, with a seam having a carbonaceous shale for roof or bands of interstratified slate, drilling by the percussive system may lead to wrong conclusions, as to thickness, quality, and the location of the impurities in the coal. This is so, because the samples obtained by this system are in minute fragments, so thoroughly mixed that the identification of any one particle and its place in relation to the seam is of course impossible, whereas the cores obtained by the rotary drill are solid and show exactly all impurities passed through as well as their relations to one another.

63. Contracts.—This work is usually done under contract at a fixed price per foot, depending on the depth and size of the hole, the number of times the machine must be moved from hole to hole, and the distance apart of the holes. The contractor supplies the machine and labor and carries on the work. Water and coal for the engine may be paid for by the contractor or company, as agreed in advance. As far as possible, the holes should be located near some road, so that supplies may be hauled in, and convenient to water, of which a large amount is required. A distinct understanding should be had in writing, signed and witnessed, as to what the contractor is to do and furnish, and particularly if he is to *guarantee a core*. If the contractor guarantees this, and fails to furnish a complete core of the coal seam satisfactory to the company, he can be compelled to drill other holes until a core is supplied. For this guarantee an extra charge will be exacted, which is worth paying.

64. Number and Location of Holes.—Whichever system of drilling or boring is finally adopted, considerable study should be devoted to the problem before any drilling contracts are let, so that the smallest number of holes necessary to do the work may be determined. The number and

location of drill holes is largely a matter of judgment and local conditions. Some companies require one to the square mile or one to each thousand acres, and where the seam from its location is very valuable and doubts are entertained as to its continuity at that point, even more may be required. When the deposits are irregular and under light cover, as in some parts of the Central Basin, holes are frequently located 80 rods apart.

The ratio of one hole to the square mile or thousand acres, though holding good, would rarely be followed for very deep seams, because of the enormous cost; one to every 2,000 or 3,000 acres would have to suffice. In flat measures the drill is located to most advantageously test the quality of the seam, the information obtained as to depth and dip being of secondary importance; but where the rocks are contorted and faulted, a knowledge of the underground structure is fully as essential as of the quality of the seam. In this case, the cross-section is prepared from the study of surface exposures and the drill located to settle any doubtful points or to discover unknown ones. How many holes are necessary it is impossible to state, each piece of contorted ground requiring separate and distinct treatment.

65. Examples of Location of Holes.— In the case shown in Fig. 7, if the analyses and sections of all the openings were up to the standard demanded by the company, probably all that would be done would be the opening of the upper seam at the head of the stream on the I. W. Hall tract, possibly also at U'. If No. *3* on the lower seam showed evidences of thinning, a hole should be put down near the southeast corner of the Wesley Holt tract. If the coal there was too thin, both Holt farms and the northern portion of the Hall farm would be rejected and another hole might be sunk near the southern and central portion of the Allen tract, particularly if more coal could be bought in that direction. On the western side of the property, if openings No. *1* and No. *2* were satisfactory and the coal as uncovered in the stream at U' showed up well, a confirmatory

hole might be put down near the northwest corner of the Jones tract. However, if the crop openings were all good, few companies would drill a property of this size unless more coal could be had to the west, in which event the hole on the Jones tract would test their property and that adjoining as well.

Large properties, shown in Fig. 9, are rarely drilled. The low price at which they are offered makes it possible for the buyer to take some chances, and the examination of the outcrop on it and neighboring properties is considered sufficient. If, however, the coal lies at some distance below the surface and does not outcrop, the deposit must be prospected by drilling.

If drilling is decided on, it should be preceded by a careful surface examination, and the information obtained by the drill used in conjunction with the surface data and not independently. In most cases, half the money spent in drilling, if laid out in a detailed examination of the surface exposures, would yield far more satisfactory results.

66. As there is no coal in or under the Mauch Chunk or Pocono formation, the drill should not be located where either of these formations outcrop. Likewise, since the Barren Measures of the Appalachian coal field are destitute of workable seams, the drill should be located within the area covered by them only when it is desired to reach the coals in the Productive Measures below. In this case the holes should be placed along the valleys of the streams flowing over the Barren Measure area, to save several hundred feet of unnecessary drilling.

In the case shown by Fig. 19, the drill holes for testing both quality and dip would be conveniently located at *R* and *S*.

Large tracts of some seams in a region of excellent reputation are bought without drilling, but this is unsafe owing to the tendency of all seams, even the most regular, to have local bad places.

67. To Determine the Direction and Amount of Dip of an Inclined Seam by Means of Three Bore Holes.—Three points determine the position of a plane passing through them; hence, it is possible from the records of three bore holes to determine exactly the plane of a seam if this is uniform between the bore holes. Assuming this to be the case, three holes are located by survey, and the elevation of the surface at each hole determined by levels. Subtracting the depth of each hole from its elevation at the surface gives the elevation of the seam at each bore hole. The strike of the seam, being a level line in the seam, is then determined by finding a point on the line in the seam joining two of the bore holes that has the same elevation as the intersection of the third hole with the seam. If a line is then drawn joining this point with the third hole, such line is a *line of strike*, and a line drawn at right angles to this line gives the direction of the dip of the seam. The amount of dip is then determined by the fall this line has in a given distance.

ILLUSTRATION.—Fig. 28 represents three drill holes located at *A*, *B*, and *C* on the surface.

As shown in the figure, the respective elevations of these holes at the surface are 980, 650, and 1,290 feet above datum. Their depths to the seam are 520, 300, and 790 feet. Subtracting the depth of each hole from its elevation at the surface gives the corresponding elevation in the seam, as shown in the figure, 460, 350, and 500 feet above datum, respectively.

As shown in the datum, or horizontal plane, Fig. 28, the holes *A*, *B*, *C* are connected by a survey as follows: *a–b*, S 82° 30′ E 2,000 feet; *b–c*, N 63° 50′ W 1,500 feet. Draw a line in the seam, joining the two bore holes that have the least and greatest elevations, in this case *B* and *C*. The horizontal length of this line as given by the survey is 1,500 feet, its total fall $500 - 350 = 150$ ft. or a fall of 1 in 10; that is to say, the line *c–b* falls 1 foot in each 10 feet of horizontal distance.

The next step is to find a point on this line having the same elevation as the bottom of hole *A* (460). This point is $460 - 350 = 110$ feet in vertical height, above bottom of hole *B*. And since the fall of the line *c–b* is 1 in 10, the distance of this point from hole *B*, or the distance bx in the horizontal plane is $110 \times 10 = 1{,}100$ feet. This determines the strike line (460), drawn from the bottom of hole *A*, as marked in the figure. Another strike line (350) is also drawn parallel to this one in the seam.

The next step is the solution of the triangles shown in the horizontal ane, to determine the direction of the strike of the seam and the dip

FIG. 28

line at right angles to this. The bearing of the line b-c is given by the survey N 63° 50′ W. The angle $c\,x\,a$, exterior to the triangle $a\,x\,b$, is found as follows:

$$\tan c\,x\,a = \frac{2{,}000 \sin b}{2{,}000 \cos b - 1{,}100}$$

$$= \frac{2{,}000 \times .32006}{2{,}000 \times .9474 - 1{,}100} = \frac{640.12}{794.8} = .80539$$

and angle $c\,x\,a = 38°\ 51'$. The line $o\,b$ being parallel to $a\,x$, angle $o\,b\,c$ equals angle $a\,x\,c = 38°\ 51'$, and the angle $o\,b\,a$ is then $38°\ 51 - 18°\ 40' = 20°\ 11'$; hence the bearing of the strike line is $(180° - 82°\ 30' - 20°\ 11' = 77°\ 19')$ N 77° 19′ E. The line of dip being at right angles to the line of strike its bearing is $(90° - 77°\ 19' = 12°\ 41')$ S 12° 41′ E.

To find the amount of dip it is necessary to solve the triangle $c\,o\,b$ to obtain the horizontal length of the dip line $c\,o$. The angle $c\,o\,b$ is a right angle, and the angle $o\,b\,c$ as found above is 38° 51′; hence, the length of the line c-$o = 1{,}500 \times \sin 38°\ 51' = 1{,}500 \times .62728 = 940.92$ feet. The total fall of this line is equal to the total fall of the line c-b as given above, $500 - 350 = 150$ feet. The amount of the dip of the seam is then, 150 : 940.92, or 1 : 6.2728, or the tangent of the dip angle is $\frac{150}{940.92} = \frac{1}{6.2728} = .15941$, and the dip angle is 9° 03′.

68. The deceptive results obtained by depending on drilling solely are well shown in Fig. 29, in the case of a seam at an average depth of 225 feet. The curved line marks the outcrop of the *guide rock*, which showed a marked syncline *B A*, besides other minor folds. The drill holes *1*, *2*, *3* were sufficient in number and well located for testing the quality of this 2,000-acre tract, but gave entirely erroneous ideas as to the dip and strike. They were located, as shown, in the valleys to save the cost of drilling through several hundred feet of measures that formed a hill over the syncline. The figures *602*, *677*, and *675* give the respective elevations of the floor of the coal seam at the foot of each drill hole. These elevations indicate that for all practical purposes the strike is the line *2–3*, or nearly at right angles to the syncline; in other words, the direction of the dip as deduced from the drill holes, and shown at *c*, was nearly 90° in error, since the true dips, as shown by the syncline, are *d* and *d*. A fourth drill hole would have revealed this error.

Fig. 29

CALCULATION OF AREA AND TONNAGE

AREA

69. To calculate the **area** of the coal seam, first add together the areas, as shown by the property map, of the farms entirely underlain with coal. Next estimate the proportional area underlain on each of the remaining farms, and add this sum to the above for the total area. Thus, if we have 867 acres covered by eleven farms, eight of these

being entirely underlain with coal, and on the remaining three there is as follows: one-fourth of 100 acres, one-fifth of 60 acres, and one-half of 138 acres, the total area underlain will then be $867 + 25 + 12 + 69 = 973$ acres, of which 89 per cent. has been determined by actual farm survey and 11 per cent. by estimation. Therefore, granting we are as much as 50 per cent. in error in estimating our partial areas, the final result would only be 50 per cent. of 11, or 5.5 per cent. astray, which is accurate enough for preliminary estimates. The final survey, if the coal is bought and paid for within the crop line, should be run with transit and tape.

When, as noted before, two seams are too close together to be distinguished on the map, the area of the second may be deduced from the first if their average horizontal distance apart has been determined as directed. To do this with a property mapped on a scale of 30 rods (= 495 feet) per inch, set a pair of dividers to 1 inch and step them around the crop. Multiply the total distance thus obtained by the value of 1 inch in feet. This will give us the length of a strip whose width is the average horizontal distance between the crop lines. Multiply this length by the horizontal distance and divide by 43,560, and the area in acres is obtained, to be deducted from or added to the area of the first seam, according as this is below or above the second.

ILLUSTRATION.—The length of crop as stepped by dividers is 42 inches; average horizontal distance between crops is 35 feet; scale of map 30 rods is 495 feet per inch. Then, $\frac{42 \times 495 \times 35}{43,560}$ = 16.7 acres, which is to be subtracted from the area of the first seam, because it is the upper one. In flat countries, where the outcrops are separated, the area of each seam must be calculated independently.

TONNAGE PER ACRE

70. Flat Seams.—To calculate the number of tons of coal underlying a property, the weight of coal underlying 1 acre must first be determined. In the case of a flat seam this is found by multiplying the square feet in 1 acre by the

thickness of the seam in feet, and that product by the weight of 1 cubic foot of the coal. The weight of a cubic foot of coal is found by multiplying the weight of a cubic foot of water (62.5 pounds) by the specific gravity of the coal. The average specific gravity of bituminous coal may be assumed as 1.3, while that of anthracite coal is 1.5.

One acre contains 43,560 square feet. Hence, for each foot of thickness of seam there are 43,560 cubic feet of coal per acre, in a flat seam. Therefore, to find the weight of coal in a flat seam underlying 1 acre of land we have the following:

Rule.—*Multiply 43,560 by the thickness of the seam, in feet, and that product by 62.5, and the resulting product by the specific gravity of the coal. Divide the product obtained by 2,000 for short tons or 2,240 for long tons.*

Example.—In a flat seam how many short tons of coal underlie an acre of land when the thickness of the seam is 5 feet and the specific gravity of the coal 1.27?

Solution.— $\frac{43,560 \times 5 \times 62.5 \times 1.27}{2,000} = 8,644$ short tons. Ans.

71. The above rule gives the total weight of coal underlying an acre of land when the seam is flat, and makes no allowance for the loss due to the extraction of the coal. A rule sometimes given, and which is used by Scotch engineers for checking the reported tonnage of coal per acre in a flat seam, is as follows:

Rule.—*Multiply the specific gravity of the coal by 100 and add 1, the result is the tonnage per acre per inch of thickness of the seam (in tons of 2,240 pounds).*

Example.—Using this rule, find the number of long tons underlying 1 acre of coal where the seam is flat and has a thickness of 5 feet, the specific gravity of the coal being 1.27.

Solution.— $1.27 \times 100 + 1 = 128$ long tons per inch per acre. Then, $128 \times 5 \times 12 = 7,680$ long tons. This is equivalent to $7,680 \times \frac{2,240}{2,000} = 8,601.6$ short tons, and shows that the shorter Scottish rule checks very closely the previous calculation.

72. In American practice it is common to estimate the *net* tonnage per acre, or the weight of coal that can be mined from a seam underlying 1 acre of land. As the methods and systems for mining coal have improved, the weight of coal mined per acre has steadily increased. A common rule formerly employed for estimating the tonnage per acre for flat seams of bituminous coal was as follows: *Estimate 1,000 short tons per acre per foot of thickness of seam.* This rule was gradually replaced by the following: *Estimate 100 short tons per acre per inch of thickness of seam.* This rule gives 1,200 tons per acre per foot of thickness, and many engineers are now estimating upon 1,400 tons per acre per foot of thickness. These rules show a steadily decreasing percentage of loss in mining.

73. Inclined Seams. — When the seam pitches uniformly, the tonnage per acre is obtained by dividing the tonnage calculated for a horizontal seam by the cosine of the angle of dip; or,

$$\text{tonnage per acre of pitching seam} = \frac{\text{tonnage per acre of horizontal seam}}{\text{cos of dip}}$$

If, in the example in Art. **70**, the angle of dip was 34°, the tonnage in the inclined seam under 1 acre of surface would be

$$\text{tonnage on pitch of } 34° = \frac{\text{horizontal tonnage}}{\cos 34°} = \frac{8,644}{.829} = 10,427$$

It is not customary to figure the tonnage closer than the nearest 100 tons. Where there are marked changes in the dip, the tonnage in each portion of the seam must be calculated separately. Where the seam is highly contorted or folded, even an approximate estimate of its contents is impossible.

IRREGULARITIES OF COAL SEAMS

74. Thickness of Seams.—Every normal seam within a given area has an average, or usual, thickness, and any unusually thick or thin portion of the seam is of small extent. This general rule does not refer to the gradual thickening or thinning common to any seam over wide

areas, but to local changes. In a great many localities the coal seam is thicker under a slate than under another form of roof. Again, a seam does not generally continue to thicken after it is once under solid cover. The common notion that a seam always thickens under a hill does not always prove true. If there are no slips, the full height of the seam is generally obtained as soon as the roof is fairly sound. Naturally, as we near the edge of a coal basin the seam thins out until it gradually disappears. Many seams, as the Pittsburg bed, for example, preserve their thickness over wide areas.

Pitching seams have much greater and more sudden variations in thickness than horizontal seams, owing to the enormous and irregularly applied pressure to which they have been subjected. Few contorted seams have a normal or average thickness in the same sense as have flat seams, the usual thickness of contorted seams prevailing over a few square miles at best.

The local thickening and thinning of seams, such as rolls, squeezes, hogbacks, etc., extending over but a few square yards or acres at the most, have been explained in *Geology of Coal*. Their effect on the value of the seam must, however, be considered by the prospector. The local thinning of a seam has more effect on the haulage and the cost of producing coal than any other item. It likewise diminishes the yield per acre, but at the usual purchase price of coal land, the loss per ton through local thinnings is insignificant, unless the irregularities are numerous. An example will show this loss under average conditions.

A fair price today for a 4-foot seam of good coal varies from \$25 to \$100 per acre, according to the locality, making the first cost of the coal, at the usual yield of 5,000 tons per acre, $\frac{1}{2}$ to 2 cents per ton. Should any acre thin to 3 feet, the loss would be $5,000 \times \frac{1}{4} \times .02 = \$25$ for that particular acre. If one acre in every ten should thin, the loss in a thousand-acre property would be \$2,500. The extra expense in haulage due to such thinning would be several times this amount, because the size of the mine car would

be reduced thereby. A larger number of these small cars must be provided, more trips made, and more drivers and mules employed to keep up the tonnage.

75. Extent of Seam.—When investigating coal seams in measures known to be ordinarily barren, we should expect that the coal area is limited to a few thousand acres at most, and make exhaustive tests to confirm this theory; while on the other hand, we find that the seams of the productive measures are remarkably uniform, even over whole counties. A notable example of extent and uniformity is afforded by the Pittsburg bed, originally extending, as proved by outlying patches, from Pittsburg, Pennsylvania, into Ohio, and West Virginia as far as the Big Sandy River, and eastward through Meyersdale and Broad Top, Pennsylvania, to Cumberland, Maryland, and over this wide area it preserved its distinguishing characteristics of thickness and quality. So uniform is this seam that often no tests are considered necessary to prove its quality, and large tracts are bought at high prices on the strength of its reputation alone.

One point the prospector must not forget is that each property offered for sale is a problem in itself. All the good coal is not in one field and all the bad in another; there are good and bad areas in each, and a field must not be condemned in advance because it is in a neighborhood usually poor. Its location should suggest caution, nothing more.

76. Character of Seam.—In the Appalachian field, as we go westward from its eastern edge, the same seam shows a continually increasing percentage of volatile matter. This constituent in the Pittsburg seam increases from about 21 per cent. at Cumberland, to 36 per cent. or more at Pittsburg. The hardness of a seam will also vary; thus, the Pittsburg, in Westmoreland County, Pennsylvania, is much harder than in the Georges Creek region farther east or at Fairmont to the south.

The coking or other qualities may change. Again using the Pittsburg bed as an illustration, because of its wide

extent, the Georges Creek steam coal, the Pittsburg gas coal, and the Connellsville coking coal all belong to this seam, yet each is the highest type of its kind.

In the Eastern States igneous or volcanic action has played no part in changing the character of the coal after its formation. Whatever changes have been effected have been brought about by metamorphism, as exemplified in the anthracite regions, but in the Western States, where igneous action is common, the original character of the seam may have been more or less altered. A gentle slowly applied volcanic or metamorphic heat distributed more or less widely over a region may result in giving a coking quality to coal that without this heat would remain in its ordinary lignitic or domestic condition. A more closely and more strongly applied heat, as that of a volcanic dike, or overlying sheet of lava or porphyry, may change the coal at contact to anthracite, or if the heat be too great, to a species of compact, hard, worthless coke, or even to pure or impure graphite; or a sudden fierce heat may entirely ruin the seam of coal by burning it out and sometimes filling its place with lava. In searching for a coking bituminous coal or anthracite, a region in which volcanic rocks predominate should be sought, or a region where original metamorphic heat may have been induced by great upturning and folding of the strata or other wide-felt regional causes.

In Northeastern Colorado volcanic rocks are comparatively rare. The coal in consequence is of a lignitic, domestic, or non-coking character. Toward the southern part of the State, volcanic dikes and sheets abound, and the coal gradually becomes of a coking quality. In the heart of the mountains, where the strata are greatly overturned, and huge masses of volcanic material have been intruded, the coal is mostly coking, while locally, near contact with the eruptive or intrusive sheets, it may be changed into anthracite. It is worthy of observation that a sheet of lava or volcanic rock may locally descend or sag down on a coal seam and for a certain distance cause it to anthracize, as it were, while but a few yards off, if the lava sheet happens to raise a

little, the coal remains in its original unaltered state as a domestic, or it may be a coking coal. So it is sometimes quite unsafe for a prospector to assume that a coal seam outcropping over a large area and overlain by a wide sheet of volcanic rock, and showing here and there an anthracitic face, is necessarily true anthracite under all the area covered by the volcanic sheet. As a rule, intrusive porphyries appear to have greater influence in changing coal than surface volcanic lava flows like basalt.

An area very much traversed by an intricacy of dikes may not be an advisable one for the prospector to select, the dikes giving constant trouble in the future workings of the mine. In locating a property of this kind, it is advisable to locate the workings so that they will cut the dikes as much as possible at right angles and not diagonally. More than one coal mine has been abandoned from the prevalence of dikes.

Large areas of coal have been spoiled by past spontaneous combustion or by other causes of burning. The burned areas can generally be detected by the redness of the surface rocks, the still burning areas by the escape of smoke and gases from cracks in the ground. It is needless to say the prospector should avoid these, while at the same time the local redness of the rocks may be an indication to him of the presence of coal in the vicinity and lead him to a locality where the coal is unchanged.

77. Faults of Dislocation.—These are of rare occurrence east of the Rocky Mountains, excepting in the anthracite measures of Eastern Pennsylvania, and, when found, are small. In the vicinity of Philipsburg, Pennsylvania, they are fairly common and may be traced on the surface by the displacement of the outcrop of the coal seams or of some stratum of hard rock, amounting to as much as 30 feet vertically. In tracing them, the coal bench will be found hazy, or perhaps lost entirely for possibly 100 feet, only to appear at another level. When occurring, they should be carefully located on the ground and subsequently on the map. In the East they

are not of enough importance to condemn a field, but give trouble in operating, as the haulage roads have to be graded through the irregularities caused by them.

In the West and in any mountain region, they may be of such great *throw* or so numerous as to entirely destroy the value of the field. In these regions their effect in decreasing the tonnage in a property is marked, but cannot usually be calculated until the fault is met underground. When large, they add greatly to the cost of production, due to the large amount of rockwork in tunnels, slopes, etc., necessary to recover the faulted portion of the seam.

78. Clay Seams.—These, together with dirt seams, gravel seams, etc., while not usually of sufficient extent to seriously affect the tonnage in a property, exert a marked influence on the cost of production because of the cost of driving through them. This is also true of old stream channels, which have cut out the coal and in which it has been replaced by sand, giving what are often called *faults of erosion.*

IMPURITIES OF COAL SEAMS

79. As a coal seam varies in thickness and extent, so will the contained impurities vary, only more rapidly and within narrower areas. In some seams this variation is more to be looked for than in others, but all coal fields have bad areas. Impurities such as slate may be removed or lessened by care in mining, or by subsequent picking or washing; others, such as ash, sulphur, and phosphorus, cannot usually be cleaned except as described later.

80. Ash.—This is so universal as to be a constituent and not an impurity. No fixed percentage can be named as a proper amount for any given coal to contain. A coal containing as little as 6 per cent. is remarkably good, and one having 8 per cent. is probably better than the average coal shipped to market. High or low ash is a relative term,

and in some sections of the country 14 per cent. of ash is considered low.

Ash may be introduced into coal from pieces of a brittle roof or of draw slate, portions of a slate binder, fragments of a soft floor, or large lumps of bone. Therefore, in examining any opening, it is important to note how the roof and floor behave; for, if the pieces breaking off from them are small, the greatest care underground cannot prevent their entrance into the coal or effect their subsequent removal. In this case the coal would have to be separated into sizes and washed or jigged, adding to the cost of operating.

81. Bone.—This is a denser or harder form of coal, of less luster and higher in ash than the rest of the seam. It is frequently found at the roof and is then left up both in the rooms and entries, unless its removal is necessary to give sufficient height for haulage. Its effect, when loaded with coal, is to increase the percentage of ash in the latter. The ash in bone will vary from 1¼ to 5 or more times as much as that in the coal, and the bone may shade into carbonaceous shale and finally true shale. When left up, bone is a great protection to a weak roof, that is, one having a tendency to soften or fall when exposed to the air.

82. Mother Coal.—This is sometimes called **mineral charcoal**, and is a soft form of interstratified carbon, usually higher in ash than the rest of the seam, shading into **smut** when the proportion of dirt is high. It is injurious not only because introducing more ash, but also in making a line of weakness in the seam, causing it to break in smaller pieces, therefore destroying the "lumpiness" so much desired in the market.

83. Slate.—This is a frequent source of high ash in coal, occurring interstratified with it, and of varying thickness. When conveniently located in a seam, the mining may be made in it, occasioning no loss of coal, but its presence is always undesirable, as it is impossible to prevent a greater or less amount getting in the coal. The large pieces

will, of course, be seen and removed, but the fine pieces mingle with the slack, and if this latter is screened out and coked, the resultant product is abnormally high in ash. Slack from slaty seams should always be washed before coking.

In this connection it is well to note that the slate, thin at one end of a field, may gradually thicken, and in the course of a few miles form two distinct seams separated by several feet of rock.

84. Sulphur.—This is the usual designation for sulphide of iron, or pyrites. It is practically a universal impurity in coal, occurring in many forms, usually as iron pyrites. The amount in any seam is apt to vary widely within short distances, sometimes rising from 1 per cent. to 2 or more in 500 feet. It may occur so finely disseminated as to be detected only by analysis, or in minute crystals on the horizontal or vertical cleavage planes of the coal, looking like yellow patches. It is found in plates an inch or more thick, and of varying width, usually at right angles or parallel to the bedding, but sometimes at an angle, or in the shape of lenses frequently several hundred pounds in weight. These large pieces may be removed in mining, but are a source of trouble and expense.

The lower portion of the seam, where the mining will be done, should be carefully examined for sulphur, as it is often concentrated in the bottom. If it is there in a fine state and is abundant, it will interfere with the marketing of the slack or its use in coke making, or if present as sulphur balls, may entirely preclude machine mining. If the piant is to be equipped with coal-cutting machines, the question of sulphur in the lower portion of the seam will determine the type of machine adapted for undercutting.

Sulphur is injurious in every way. As it is combined with iron, it adds to the percentage of ash. It helps to form a fusible slag or clinker with the other impurities of the coal, clogging the grate bars, and its fumes have a corrosive action on the steel of the boilers. If present in large

amounts, it renders the coal liable to spontaneous combustion, owing to the heat evolved by its decomposition under atmospheric moisture and heat, something particularly noticeable with slack. It also renders the coal unsuited for forging iron or coke making.

85. **Phosphorus.**—This impurity is only considered when the coal is to be used for the manufacture of coke. The amount present in any seam, though small, will vary widely in short distances; .02 per cent. is the maximum amount of phosphorus allowable in coke for Bessemer iron making, and as none of this element is removed in coking, and because on an average 1½ tons of coal yield 1 ton of coke, coking coal should not contain over .013 per cent. of phosphorus.

86. **Other Impurities.**—**Lime** is sometimes present in coal in the ash or as sulphate or carbonate. It has a tendency, owing to its decomposition by the carbonic acid in the air, to form carbonate of lime, making the coal white. It also mixes with the iron and alumina in the ash to form clinker.

The alkalies, **soda** and **potash**, while present in the ash, are rarely of sufficient amount to be worthy of attention.

ANALYSES AND TESTS OF COAL

87. The **analyses and tests of coal** that should be made in connection with the examination of a coal property, are (1) *field tests*, which are made by the prospector himself or under his direction, and (2) *laboratory tests*, requiring delicate and often expensive apparatus unsuited for use in the field and usually requiring an expert chemist for its manipulation. The principal field tests are given in the following paragraphs.

88. **Chemical Analysis.**—This may be made to determine either the ultimate or proximate composition of the

coal. In the former, the percentage of each element—carbon, hydrogen, oxygen, nitrogen, and sulphur—is determined. This is rarely done, owing to the time, skill, and delicate apparatus required; on the other hand, a proximate analysis of coal determines readily, without any costly appliances or much skill, the proportion of water and ash present in any given specimen of coal, and the proportion that the volatile matter bears to the fixed carbon, and this will sufficiently determine the value of coal as a commercial commodity.

89. Coking Qualities.—These are generally tested by sending a powder or nail keg full of the slack to the nearest coke plant, where it is placed in an oven, covered with the usual charge of slack, and drawn out when the oven is pulled. This is, however, entirely too small a quantity from which to determine the coking qualities of a seam. At least two carloads should be shipped to some coke plant, so that one or two ovens may be run on the mine run coal for a week or more. If the mine run does not yield a satisfactory coke, it is well to grind 40 or 50 tons to slack and again try the coal, for many coals that will not coke when lumpy will coke very well when powdered. If this is found to be the case, it will involve the question of grinding and elevating machinery at the mine. Should it be the intention to ship the lump and coke the slack, enough coal should be mined to furnish a carload of screenings for test. This will give a very good idea of the quality of the coke obtained when the plant is completed, something that grinding mine run will not do, because the slack always contains more impurities (due to fine pieces of slate, the usual concentration of sulphur in the lower part of the seam, etc.) than does mine run. If the analysis of the trial lot of coke shows too high a percentage of ash and sulphur, a carload of slack should be sent to the manufacturers of coal-washing machinery and have it passed through their experimental plant. The washed coal should be sent to the ovens, and the resulting coke will probably come within the limits of purity.

As ash is not removed in the coking process, and because, on an average, it requires 1½ tons of coal to make 1 ton of coke, a coal containing 6 per cent. of ash should yield a coke containing 9 per cent. If the analysis shows more ash than is proper for the coal used, it is due to the entrance of impurities into the slack during mining, and these can generally be avoided, all or in part, by care on the part of the men or improvements in the methods of mining.

It is well to examine a new property closely for the behavior of the roof and floor. If these spall or flake off in small pieces, they can hardly be removed by the men and an expensive washing plant will be necessary, the cost of which might condemn the property.

90. It was noted before that the amount of sulphur and phosphorus in a seam will vary widely in short distances, and since the blast-furnace manager requires a coke not only low in these impurities but also uniform, this variation must be carefully investigated in the mine. The superior limits of the various impurities in Bessemer coke, that is, coke suitable for making iron to be used in the Bessemer steel process, are generally given as ash 10 per cent., sulphur 1 per cent., and phosphorus .02 per cent. A coke that varies but slightly from these figures is a more desirable fuel than one that, though averaging purer, frequently and unexpectedly runs higher.

The ash and phosphorus in coal are not removed during coking, whereas one-third to one-half the sulphur is volatilized, and allowing, as before, 1½ tons of coal to 1 ton of coke, a coal analyzing ash 6.50 per cent., sulphur .75 per cent. to 1 per cent., and phosphorus .013 per cent. should yield a coke within the Bessemer limits.

91. Efficiency of Coals. — The **efficiency of a coal** means the amount of work done by it in raising steam, and is usually expressed in terms of the number of pounds of water evaporated into steam by 1 pound of coal. Theoretical efficiency expresses what the coal should do when economically consumed under favorable conditions and may be

determined by experiment with the calorimeter, by the lead test, or by calculation from an analysis; actual efficiency is that obtained in practice, and can only be determined by using the fuel under boilers. The efficiency of coals is frequently expressed in terms of British thermal units, though chemists, using the metric system, give it in calories.

PRECAUTIONS IN EXAMINING OPENINGS

92. On properties where the coal outcrops, and where a number of small openings exist, each should be located on the map, and if there is room, beside this should be written the name of the mine, and the seam and its thickness, thus: "Shultz Mine—A—39." If there is no room on the map, a number should be placed at the drift corresponding to one in the field book, where this information should be entered. Where openings have been allowed to fall in, unless within a short distance of another accessible drift, they should, where possible, be cleaned up and put in shape for examination. Always insist on seeing every part of an opening, particularly the abandoned portions, for it frequently happens that these sections were stopped because the coal was thin or poor. This is exactly what the prospector was sent to learn, and he must be on his guard against interested parties trying to prevent a thorough inspection.

The thickness of the coal should be measured as soon as under solid cover, at the face of the main entry and at the face and mouth of each branch. The ribs should be inspected foot by foot for any variation in the nature and amount of the impurities or to discover those not generally present.

If any miners are at work, learn from them how the coal works, that is, how it mines and shoots, and if the hardness of the seam varies in different portions of the mine, or from other mines in the vicinity in which they may have worked. Inquire of the miners as to the presence of spars and sulphur balls (iron pyrites), their frequency, size, and location in the seam. Inspect the gob for impurities thrown out in mining

and for any traces of spontaneous combustion. Note how the coal weathers. Something can be told about this if the age of the entry is known. Some coals weather more rapidly than others, turning white in two months. Such coal will not bear stocking or long voyages.

93. If the mine is selling lump coal to the neighborhood, examine the slack pile for traces of spontaneous combustion. From surrounding chimneys it may be noted whether the coal yields much or little smoke, and ash heaps will show presence or absence of clinker; note the size and color of the ash pile and the amount of clinker. Red ash denotes iron, and this usually means sulphur. Have the man in charge "fire up"; watch the stack and note the time required for the heavy black smoke to pass off. Also learn from the fireman the good and bad qualities of the coal from his standpoint.

If there is a mine shipping coal nearby, note the appearance of the coal on the railroad cars and estimate the percentage of lump if loading mine run, and learn if the coal will bear screening. If possible converse with the pit boss, and learn his ideas on the coal seam and its working. Any peculiar or local difficulties he may have met are especially worthy of note. Inquire of him as to the presence of faults, rolls, horse backs, irregular dips, clay veins, sulphur, the behavior of the roof and floor, and any troubles experienced in drawing pillars. Note how the roof acts, if it is heavy or if small pieces fall off, and learn if the floor heaves, owing to softening of the fireclay by moisture, and if there is a tendency to squeeze. Particularly examine the bottom of the seam for anything that may interfere with machine mining. Examine into the shooting qualities of the coal, that is, if much or little powder is required to bring down the coal after it is undercut, and if the coal breaks up much when blasted.

94. The presence of gas should always be very carefully looked into and some estimate formed of the amount of

water to be hauled. The water supply should be investigated, not only that necessary for drinking purposes, but also to learn if enough is available for steam raising or watering coke ovens. In this connection it is well to learn what the streams on the property will yield in the dryest season, also what success has been met in drilling for water. The possible sites for erecting the plant and building the necessary houses for the employes should be examined, and careful measurements made to learn if there is enough room for the side tracks. A rough estimate of the grade per hundred feet from the property to the main line of the railroad should be made, and the length and character of any bridges noted, as well as the behavior of the stream in flood time. Some notes should be taken on the rate of wages paid day hands in the neighborhood, on the cost of mine ties, wooden rails, props, and building lumber. In fact, no detail that will throw the slightest light on the difficulty and cost of mining is too small to be neglected.

THE FINAL REPORT

95. The report on any one property will not usually have to cover all the points explained in the preceding text, the ground to be covered being comprised in the instructions given the prospector before starting into the field. In all cases, the report should be as brief as is consistent with clearness. It should not be ambiguous; that is, facts should not be stated in such a way that opposite conclusions can be deduced therefrom. Some reports are marvels of ambiguity, so much so that if the property turns out badly, the particular page and line may be pointed out where this was predicted, or if the property proves good, the same page and an adjoining line is shown in confirmation. The prospector is usually called on to present the facts in the case as he sees them, leaving the deductions to be made by his employer. Where his opinion is asked, it should be given

as concisely as possible. In a report made to an investor who is not supposed to be familiar with mining operations, the prospector is allowed and expected to exercise more latitude in expressing his opinions on various points connected with the report than if the same is made to an individual or company already in the coal business. A report as ordinarily made on a medium-sized tract, the purchaser being a coal company, consists of two parts and should cover the following points.

MAP

96. The **map** should show the property lines and meridian (bearings and distances not necessary), drawn to an approximate scale of, say, 40 rods to the inch. Each property should bear the owner's name and the acreage. If there is any difference in the extent of the title conveyed in the different tracts, the words, fee, mining right, or surface, respectively, should be used under the acreage. The main streams and all canals, railroads, bore holes, and openings should appear. The latter should have affixed a reference number, the thickness of the coal, and when determined, the geological name of the seam. The outcrops of the workable seams should be noted and enough elevations on these and along the stream shown to give the dip of the coal, use of the stream, and available height for tipples. It a marked anticline or syncline has been located, it should be shown on the map, as well as the direction and amount of dip and the direction of the butts and face cleats. If the country is steep, the foot of the hill nearest the stream on which the plant will have to be built should be noted, so that the management can see if there is enough room for constructing a plant without unusual expense for grading. A few elevations taken on the hills should be shown, so that the average amount of cover on the seams, and consequent size of pillars, is clear. The position of any drill holes should be shown on the map with a proper number affixed. If a vertical section of the measures has been made,

this might be placed at one side of the map, together wi sections of the seam at various openings. The title of tl map should recite the owner's name, location of the proper and scale, the number of acres separated according to titl and usually the number of acres in each workable seam.

REPORT

97. The **report** should be typewritten, the signature the prospector, his office, and the date appearing at the en The report should cover the following points:

98. Location.—The state, county, township, total nu ber of acres, and how divided according to title; name railroad, canal, or stream on which situated, and distan and direction from nearest station thereon; if none of th exist on the property, the distance of the tract by the sho est practicable route from the nearest means of transpor tion, as well as the direction and distance from the juncti to some prominent town; the name of any nearby min with that of their operators, and the distance and directi to the same.

99. Legal Questions.—Anything the prospector m have heard or noted affecting the title of any of the co ponent properties in the group, or which may be apt cause difficulties in securing surface room for the plant right of way for the railroad.

100. Geological Features.—The presence or abse of anticlines or synclines, when occurring, their location the property; direction and dip of the same; the dip of seam, local or irregular dips observed at coal openings or outcropping strata; the direction and strength of the b and face cleats. An explanation of the vertical secti shown on the map should be inserted in the report; nature and location of any faults, rolls, horsebacks,

veins, etc., observed on the property under consideration or on adjoining lands; average cover on upper seam.

101. Surface Features. — Character of the surface, rough or smooth, elevation of highest hills, average elevation; nature of valleys, width and inclination; water supply, for drinking, steam purposes, coal washing or coke making; variation in streams in summer and winter; length and grade of railroad required to reach the plant, conditions affecting its cost, point where branch would leave main line, etc.; character of location for building town and plant, favorable or unfavorable, much or little grading, width of bottom lands, height of coal above grade; amount of timber on property and purposes for which suitable; available labor in the region, teams, cost per day; source of ordinary supplies, as, for example, nearest wholesale iron, grocery, and other establishments.

102. Coal.—Number of workable seams on the property and acreage underlain by each; their geological name if determined; how examined, by shafts or outcrops; a detailed account of each opening, with section of the seam, accompanied by analysis; openings made by prospector; thickness and dip of seam and variations in same; nature and thickness of contained slates, bone, mother coal, or bands of sulphur, variations in the thickness of impurities, ease of separation from coal; sulphur balls, place in seam; results of examination of bottom for sulphur as affecting use or type of mining machinery; comparison of impurities on this and nearby properties; character of roof, thickness and behavior of draw slate, weathering, spalling off, rock above draw slate; character of the floor, regular or irregular, tendency to heave, thickness of fireclay; amount of water given off by seam, color, taste; character of the coal, variations in benches, hard or soft, bright or dull, screening qualities, weathering, cleats, etc.; easy or hard cutting or shooting; qualities of these outcropping and underground seams as recorded by the drill; further comparison with

nearby properties; amount of smoke given off by coal, how observed, coking qualities as seen in fire; comments on the quality of coal from reliable sources, quoting authority; special tests of the coal for coking or steam raising, where and when made, and by whom.

103. Summary.—Comparison of this with other properties visited in behalf of the same employer; comparison with other properties in the neighborhood; any special advantages or disadvantages of the property under consideration.

Residence, signature, date.

ˀTS, SLOPES, AND SHAFTS

INTRODUCTION

finitions.—Excavations for the purpose of devel-
ıeral deposits below the surface are termed **mine**
. They may be horizontal, inclined, or vertical,
largely on the facilities with which the material
ined, brought to the surface, and handled. They
·iven in the mineral deposits or, if the geological
are adverse to this, they may be driven in the
:ent to and underlying or overlying the deposit.
ıings are also used for hoisting or haulage, and for
ınd ventilation purposes. A mine may be opened
tunnel, *slope*, or *shaft*.

ms *drift*, *tunnel*, and *adit* are applied in different
o any horizontal or nearly horizontal mine opening.
general use of the terms in coal mining is, how-
ɔllows: A **drift** is such an opening driven from
e in the deposit. A **tunnel** is such an opening
·ock outside of the deposit being worked, and may
ɔr both ends in daylight or dark; when a tunnel is
ɔss the measures it is often called a *cross-cut tunnel*.
adit may apply equally to either a drift or a tunnel,
ally implies that such opening is driven from the

› is any inclined mine opening. In many localities
lope refers to an inclined opening in the deposit,
nclined opening driven in or across rock strata is
ck slope. If the deposit is not sufficiently wide to
a proper-sized excavation, it may be necessary to

drive the slope or drift partly in the deposit and partly in the rock, above or below the deposit, but usually below.

A **shaft**, as the term is commonly used, is a vertical mine opening. In some localities, particularly at ore mines, a highly inclined slope is called a shaft, or sometimes an *inclined shaft*.

A tunnel, slope, or shaft that starts from the inside workings of a mine and is not open to daylight at either end is called an *underground*, *inside*, or *blind tunnel*, *slope*, or *shaft*. A *winze* is a blind shaft connecting levels. The surface end of a tunnel or drift is its *mouth*. The upper, or surface, end of a shaft or slope is called its *head*, *mouth*, or *top;* the lower, or bottom, end is the *foot*.

A **level**, or **lift**, is a practically horizontal underground passage or tunnel driven from a shaft or slope at any depth, and affording access to an inclined seam or deposit. These levels, or lifts, are numbered in succession from the surface downwards, and are known as *first level*, *second level*, or *first lift*, *second lift*, etc.

OPENING A MINE

LOCATION OF OPENING

2. The exact location of the opening on a property should be determined by a careful study of the territory to be worked, its extent, the configuration or character of the surface as affording a suitable site for the surface plant, the shipping facilities, and the inclination of the seam as affecting the economical haulage and drainage in the mine. Attention should also be given to prospect openings or former shafts, drifts, or slopes on the property, which may be utilized to advantage as second openings or escape ways for the proposed workings.

The character of the surface plant will generally affect the location of the opening, especially in a hilly country. The amount of space required about the mine opening for the surface plant and the character of this plant depend on the

nature of the coal—whether coking or non-coking, and if non-coking, whether it is to be shipped as run of mine or in prepared sizes—and on the amount and character of plant needed for hoisting or hauling the coal to the surface. The amount of capital available determines largely the magnitude of the undertaking, or the daily output, and hence also determines the character and extent of the surface and underground equipment. A suitable level site for the surface plant should be chosen, if possible, and ample allowance made for necessary buildings, tracks, and supply yards. While it is possible to bring both timber and water to nearly any location chosen for the opening, yet, other things being equal, the nearer the opening can be located to the timber and water supply the better, for it will lower the cost of operating the mine.

3. **Transportation.**—The location of an opening is also influenced by the means of transportation to be used; whether it is by railroad, ship, canal, team, pack train, rope tramway, etc. Transportation by railroad, when possible, has the advantage of putting the coal quickly on the market, and the railroad also is a possible consumer. The disadvantages of railroad transportation are the high rate paid for transportation and the frequent inability to secure cars at the time when most needed. Numerous coal roads and short branches are constructed exclusively for the development of certain fields. Transportation by ship or by canal is slower, but affords cheaper rates, allowing the coal to enter markets from which it would otherwise be excluded. It often happens that a choice between these several methods of transportation is afforded in a given locality, and the mine opening may then be located so as to avail itself of the advantages of each. Transportation by team is employed to supply local trade, and sometimes, at small mines, to transport the output from the mine to the railroad siding. Transportation by pack train is employed only in mountainous districts where other means are not available.

4. **Property.**—The extent of a coal property owned, leased, or controlled, varies from 40 acres to several thousand

acres; it may be wholly or partially prospected. A large property should be opened and developed from the point where the prospecting has given the best results, provided that proper shipping facilities are found at such point.

The opening should be located as near as possible to the railroad, or other means of transportation. If it must be located away from the main railroad, a map of the branch or siding to connect the proposed site with the main line should be submitted to the proper railroad official for his approval before work is begun. Such a map should show the degrees of curve, the grades of track, and the amount of iron required. In many localities, it is customary for the grading to be done by the mining company, while the railroad furnishes and lays the ties and iron, on which the mining company pays interest, for they remain the property of the railroad. Suitable grades above and below the opening should be available for the necessary loading tracks, and a sufficient length of track room for at least 1 day's run.

A general idea of the contour of the deposit will, in most cases, have been obtained from prospect holes, and in an inclined seam the opening should be placed at the lowest part of the deposit, if practicable, so that the workings will drain by gravity and the haulage grades be favorable to the loaded trips. If the seam is flat and opened by a shaft, it should be placed in the center of the field, if possible, and so located that prospective additions to the property can be worked from it.

5. The amount of territory that can be economically reached or worked from one opening will depend on the system of haulage employed and the physical characteristics of the seam. It is possible to extend a system of rope haulage a distance of 6,000 or 8,000 feet from the mouth or opening of the mine. While this will permit the mining of 1,000 acres from a single shaft centrally located, generally there are conditions that render it advisable to restrict the acreage reached from a single opening to 800 or even 600 acres. Among such conditions are the demand for coal, which requires the operation of several collieries at once;

d the nature of the roof or floor, which is frequently such it the cost of maintaining long haulageways is greater in the expense of sinking another opening and moving plant. In the systematic development of a newly quired territory, an estimated acreage varying from 600 1,000 acres may be allowed per opening.

5. **Second Opening.**—In the location of a **second, or** **cape, opening,** the use to which this opening is to be t and the requirements of the law relating to second open- gs must be considered. The law usually requires such enings to be located a certain distance from the main ening in order to insure a safe escape way in case of cident. It is usually desirable that the distance between ese openings should not be greater than is absolutely cessary for safety, in order to provide good circulation as rly as possible; but if a second opening is to be used as main opening for hoisting the coal after the territory about first opening is worked out, it may be located at a con- erable distance from the first opening, so that as large an a as possible can be developed from it.

t is often desirable to utilize the second opening for con- ting necessary wires or air pipes into the mine. When location of this opening is suitable, and especially if it an upcast for the return current of the mine, it is of antage to locate the pumps at this opening in order to id the annoyance of the exhaust steam at the main open- . Owing to the possibility of freezing, however, the nps should not be located at the downcast, or the intake, the mine. It is usually preferable that the ventilating paratus be placed at the second opening; this depends, wever, to some extent on the system of ventilation ployed, the gaseous condition of the mine, and the kind ventilator adopted. If the second opening is an upcast ening for the mine, it is advisable that its location be at a her point in the seam or on the hill than the downcast, order that the ventilation may be assisted as much as sible thereby.

CHOICE OF AN OPENING

7. Economic Considerations.—No absolute rules can be laid down as to which form of opening should be used, as this must be decided by local conditions, the most important of which, in coal mining, is probably suitable shipping facilities. In general, however, it can be stated that from the following economic reasons a drift is used wherever possible; next, comes the slope; and lastly, a tunnel or shaft.

The expense of driving a drift is generally wholly or partly covered by the value of the material taken out; the deposit is at the same time prospected to some extent. A drift permits gravity haulage and drainage, thus reducing the cost of haulage machinery and avoiding the use of pumps; the opening is safe from accident due to runaway cars, but it is not of any assistance in the ventilation of the mine.

A slope driven in the deposit also prospects the deposit to a certain extent and the cost of driving is wholly or partly covered by the value of the material taken out. A slope opening assists in ventilating the mine according to its inclination.

A tunnel opening permits gravity haulage and drainage, and, in hard rock, requires less timber than either a drift, slope, or shaft. A tunnel prospects somewhat the overlying and underlying strata, but not the deposit itself, except at the one point where it is cut. The expense of driving a tunnel is generally greater than that of driving a drift or sinking a slope in the deposit, although generally less than that of sinking a shaft.

A shaft prospects, to a certain extent, the measures overlying the deposit to be developed and greatly assists in the subsequent ventilating of the mine. With either a slope or shaft, the expense of getting the material to the surface is much greater than with a drift or tunnel; also, there is always present the liability of men and material falling down the shaft. The expense of sinking and timbering a shaft is generally greater than for any other kind of opening.

8. Geological Considerations.—The kind of opening, as well as its location, is largely influenced by the geological features of the locality. Any faults, rolls, or watery strata overlying the coal, or other geological disturbances that may be met with, influence the character and location of the opening, but no general rule can be given to govern such conditions. Seams overlaid with a slight depth of cover are often successfully worked by the quarry system known as *stripping*. A seam, outcropping on the property at a point where good shipping facilities can be obtained at a minimum cost will generally be opened at such point by a drift if the seam is

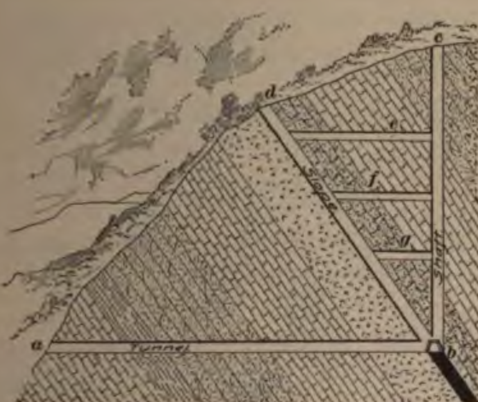

FIG. 1

flat or nearly flat, or by a slope if the seam is inclined. A seam outcropping on the property at an unfavorable point for shipping or for the erection of the surface plant may be opened at this point, and the mine cars hoisted or lowered by gravity to a more suitable shipping point below. If the seam dips strongly into the hill, it may be advisable to tunnel from a point lower on the hillside than the outcrop to intersect the seam, such tunnel providing good haulage and drainage for the operation of that portion of the seam lying above. If the deposit does not outcrop on the property, a shaft or rock slope is usually employed.

A deposit that pitches at a steep inclination may be opened either by a slope *d b*, a shaft *c b*, or a tunnel *a b*, Fig. 1. The shaft *c b* may be driven to the deposit before development is commenced, or cross-cuts *e*, *f*, *g* may be driven to intersect the seam as the shaft reaches these depths. Openings on the outcrop, either slope or drift, may be cheaper in first cost, but they may prove very expensive in the operation of the mine; on the other hand, a shaft, tunnel, or rock slope may make an expensive opening, but may prove very economical in the subsequent operation. In such case, the amount of capital available will often decide the character of the opening chosen.

FIG. 2

9. Fig. 2 illustrates each of the different kinds of openings, and their locations with respect to the shipping facilities for a coal mine. It shows a valley located over one slope of a broad anticline, giving opportunity for slope openings and shafts on the left bank of the river, and drift openings and strippings on the right. The drift opening *a* is shown loading its output into canal boats. The area in front of this drift was formerly a stripping, but when the surface had been removed as far back on the outcrop as practicable or economical, a drift was started and the mine opened. In Fig. 2, *b* is a drift

opening on a higher seam, from which the output is lowered to the tipple over an inclined plane and shipped by river; *c* is a stripping from which the surface is removed by steam shovel and the coal loaded into a canal or river boat; *d* is a slope opening driven down on the same seam as *a* and *c* and located directly on the line of a railroad, which furnishes suitable shipping facilities; *e* is a shaft opening to the seam opened by the slope *d*; *f* is a slope opening on an upper seam (the same as *b*), whose outcrop can be traced a considerable distance along the hillside beyond. The plant is located on a favorable bench of the foot-hills, and the output will go by gravity plane to the tipple at the railroad; *g* is a drainage tunnel driven to intersect the seam opened up by the slope *f*.

DRIFTS AND TUNNELS

DRIFTING

10. As the work of driving a drift, ***drifting***, grades insensibly into entry driving, these subjects will be treated together. Drifts are used for exploration or prospecting purposes, for airways, haulage roads, traveling ways, and drainage purposes; and in planning their size, shape, and timbering, the purpose for which they are to be used must be considered.

The size of the drift depends on the output desired, the size of mining cars to be used, the character of the haulage, the thickness and character of the deposit, and the character of the top and bottom rock. A weak rock often necessitates a narrow opening. The height of the drift should not exceed the thickness of the seam, unless absolutely necessary, as *brushing* (taking down) the roof or *lifting* (taking up) the bottom is always expensive dead work. The average height is from 5 to 7 feet, but when possible there should be 6 feet clearance above the top of the rail, so that a man can walk without stooping. The width varies from 5 to 10 feet, for a single-track drift, to 14 feet for one that is double-tracked.

A fair, average-sized single-track drift is 6 feet wide at the top, 7 feet at the bottom, and 7 feet high in the center. Ample space should be allowed along the side for men to pass moving cars in safety and for a drainage ditch, air pipes, electric wires, etc.

11. Number of Tracks.—The question of a single or double track should be decided before the work is started, but a single-track opening may be widened for a double track at any time in the later development of the mine, if a pillar of sufficient size is left along the passageway. Fixed rules cannot be given as to the size of a tunnel or as to when it should be built for single and when for double tracks, but the tendency is toward double tracks for short distances, and single tracks for long distances with partings or turnouts for the passing of cars going in and out of the mines.

In coal mining, the drifts are more frequently double-tracked and are usually made larger than in ore mining, as the mine cars are larger, the amount of materials transported through them is very much greater, mechanical haulage is much more used, and a larger volume of air for ventilation is necessary.

Instead of a single wide opening being driven, two or three openings are frequently used, particularly when the strata through which the drift is driven are of such a character that a wide opening is impracticable. Separate single openings are safer and often cost less to maintain than wide openings divided into compartments, but wide passageways are generally more cheaply driven than two single passageways of the same area. The material left between two openings is called a *pillar*. The weight of the strata resting on the pillars increases with the depth below the surface, hence the thickness of the pillars should increase as the depth of cover increases, or a sufficient thickness should be provided at the start to meet all future requirements. The thickness of the pillar between openings depends on the character of the rock and coal, depth of cover, and the method of mining to be employed.

12. The **grade** of a drift should be sufficient for drainage, and be inclined toward the mouth of the opening, i. e., in favor of the loads. The theoretically perfect grade is one on which the pull required to return the empty car to the face is exactly equal to that necessary to bring out the loaded car; but, as timber and supplies must be taken in, and since the track is not in uniformly good condition, this perfect grade is never attained. The grade should be at least from 3 to 5 inches in 100 feet and should not exceed 1 or 2 per cent. With a grade under 1 per cent., the drainage is apt to be sluggish unless the side ditch is kept perfectly clean.

A gutter, or ditch, is usually cut along one rib to carry off the water, and if the bottom is clay or other material that will wash away, a wooden trough is laid in it. If for any reason the grade of a drift or tunnel is such that drainage is not accomplished by gravity, a steam jet, pump, or siphon is used, the drainage pipe being usually laid on the floor at one side of the track, or hung on the side timbers.

FIG. 3

13. Beginning a Drift.—In beginning a drift, an open cut is first started in the side hill. Its width at its face should be somewhat wider than the drift, and the two wings, or side walls, should diverge outwards. As shown in Fig. 3, it should be continued until its height at the face is about 3 or 4 feet greater than the height of the desired opening.

At this point, if the roof rock has been exposed, or if the strata are sufficiently firm to be supported by timbering, a substantial set of timbers is placed in position and drifting in coal is begun. If the material forming the roof is loose, the method of forepoling, which is described later, is used until a firm roof is reached.

Drifting may be carried on either by first undercutting and shearing the coal, as shown in Fig. 4, and then, if the coal does not fall by its own weight, wedging it or blasting it down; or by bringing down the coal entirely by blasting, as is the case in tunneling in rock.

FIG. 4

When the drift is from 6 to 10 feet wide, the work is called *narrow work;* when it is wider than this, it is *wide work.*

14. In **narrow work**, the miner shears the rib on one side, and undercuts the coal to a depth approximately equal to the thickness of the seam, in seams not over 6 or 7 feet thick, as shown in Fig. 4. A shot is then placed near the unsheared rib. It is essential to avoid a *tight shot*, or a shot that is not given sufficient opportunity to work, and a shot should not be placed too far on the solid. There is not the opportunity here, as in driving a room, to *grip* the shot, that is, to incline the hole at an acute angle to the face; but in narrow work the hole must be drilled more nearly parallel to the rib. The holes are generally shorter than in room work.

The position and depth of the hole depend wholly on the shooting character of the coal. This varies in every seam, and the judgment and experience of the miner alone will

dictate the best position and direction. Some seams may be worked by a single hole, but, in general, two holes are required to give the best results. In almost every seam, there is a softer and a harder stratum of coal. It is necessary to give the hole such a position and direction as to locate the charge so that its force will be expended more against the harder stratum. The hard coal may be at the roof of the seam, or it may lie next to the floor; or the hard coal may be central in the seam with a soft stratum above and below it. The coal may break freely at the roof, or it may have a tendency to hold fast to the roof. No rule can be given for these conditions except the general rule that the charge must always be located behind the greatest resistance. A charge located in a soft stratum will often

(a) (b) (c)

FIG. 5

cause the coal to *seam out;* the soft stratum alone will be blown out by the force of the blast, the harder coal remaining in place. When coal tends to seam out, the hole should always be inclined upwards or downwards across the strata, and the charge located in the harder stratum.

Fig. 5 (*a*) shows the position and direction of the hole where a single shot is used to bring down the coal. The harder stratum lies next to the roof and the coal breaks freely at the roof. Such a hole in a 5-foot seam may be started 2 feet from the floor, 4 feet from the right rib, and inclined upwards and to the right at an angle of about 30°. The hole may be bored 4 feet deep, the shearing and undercutting being 2 feet in depth; this will locate the charge but slightly on the solid or beyond the face of the shear.

Fig. 5 (*b*) shows the position and direction of the holes when two shots are used to bring down the coal, owing to the upper stratum being harder and not breaking freely from the roof. The holes are fired separately.

It must be remembered, in locating a shot, that the weight of the coal is downwards, and with a good undercut and shear the weight assists in bringing down the coal shattered by the force of the blast. In both the cases illustrated, Fig. 5 (*a*) and (*b*), the charge has been located in the upper stratum where the coal is harder. Fig. 5 (*c*) shows the position and direction of a hole when the lower stratum of coal is the harder. The undercut is in the underclay, and the coal breaks freely at the roof. It will be observed that the position of the shot is about central in the seam and inclines slightly downwards, having been started at a higher point in the face than in Fig. 5 (*a*) or (*b*). This position of the charge will cause the fracture of the hard stratum of coal at the back of the undercut, and the soft stratum above will also be broken.

When the coal is down, it is broken by sledges, if necessary, and loaded on the car. The rib on the opposite side from the shear is then trimmed as may be necessary. The operation is repeated by putting in another undercut and a new shear either on the same or the opposite side of the face.

15. Wide Work.—In driving a wide place, the coal is sheared close to one rib and undercut as before; but the shot, more or less inclined, is placed near the center of the entry. The shearing and undercutting are usually made deeper than in narrow work. When the coal has been removed from one side of the drift, or entry, the same operation is repeated by shearing the rib on the other side and undercutting the coal, the shot being placed, as before, near the center of the entry but inclined in the opposite direction. The place is thus advanced in steps—first on one side and then on the other.

When a *draw slate* overlies the coal, it is usually allowed to remain up at the face. If necessary, one or two props are

stood a short distance back from the face to protect the miners. The slate is either allowed to fall in the entry, say 20 or 25 yards back from the face, or it may be wedged down later to secure greater head-room for the timbering and the cars. In order to avoid removing too large an amount of dirt from the mine, when there is a heavy draw slate, or to provide head-room in a thin seam, a wide drift, or entry, is driven and the draw slate, as it falls, is built along the rib as shown in Fig. 6.

FIG. 6

16. The cost of drifting varies according to the width of the opening and the conditions of the seam. For narrow work, the miner is usually paid *yardage;* i. e., a certain sum per lineal yard of advance, the amount depending on the locality, the size of the drift or entry, and the character of the coal. He is sometimes also paid for the coal mined. In some localities, instead of yardage, the miner is paid an extra price per car or ton. In wide work, the miner is paid by the car or ton and is very seldom paid yardage. In ordinary coal, two men will drive an 8-foot entry from 4 to 6 feet in a shift of 8 hours. An average price for yardage in a 5- or 6-foot seam is $2.

17. Firing time is a specified time at which the firing of shots in the mine begins. In entry driving or drifting, it is necessary to fire at shorter intervals than in room work; in many mines, firing is permitted in entries as soon as the holes are ready, although it may be prohibited in the rooms in the same mine except at firing time.

18. Blasting Without Cutting the Coal.—If the coal is neither undercut nor sheared, the method of driving differs from the methods given in Arts. **14** and **15** only in so far as these methods are modified by the character of the coal. In general, it can be said that fewer holes and a weaker powder are needed for coal than for most rocks. In tunnel

work, it is usually immaterial how much the rock is brok
by the blasting; in drifting in coal, however, care must
exercised in locating and charging the holes so that the c
will be broken as little as possible.

TUNNELING

19. The directions given as to the use, size, number
tracks, grade, drainage, etc. of a drift apply equally to
tunnel. When a tunnel is driven from the surface, an o
cut is started, as in the case of a drift, but the subsequ
work of driving, its rapidity, and the method of securing
sides and top, depend on the character of the strata throu
which the tunnel passes.

20. Tunneling in Loose Ground.—Forepoling
used in loose ground to support the top and, sometim

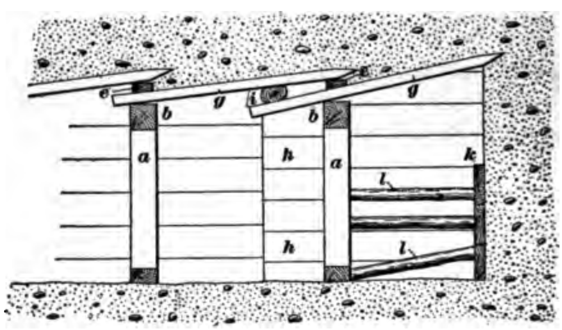

FIG. 7

the sides of tunnels. It consists in driving sharpened piec
of narrow plank, or lagging, into the roof at a very slig
pitch. The lagging rests on the collar of one timber set a
is held firmly by having its end underneath the next timb
toward the outside.

In Fig. 7, *a* are the posts of sets of timbers, *b* the cap
and *e* the top bridging. The front ends of the spiles fro
any given set rest on the bridging of the next advanced se
and the spiles for advancing the work are driven betwe

the bridging and the set, as shown. To force the spiles into the ground, so as to provide room for the placing of the next set, tail-pieces *i* are placed behind the back end of the spiles as they are being driven. After the spiles have been driven forwards the desired amount, another set is placed, the tail-pieces knocked out, and the front end of the spiles allowed to settle against the bridging of a new set. Where the face is composed of extremely bad material, it may be necessary to hold it in place with breast boards *k* held in place by props *l* that rest against the forward timber set. In a similar manner the side lagging *h* is placed in position. When breast boards are used, it is generally necessary to employ foot and collar braces between the sets, so as to transfer the pressure of the breast back through several sets.

The method of starting the forepoling at the mouth of the drift is shown in Fig. 3. Several sets of timbers are set up and long lagging driven over them into the earth beyond. By balancing the pressure of the earth on the points of the lagging with a weight of stone or timber on the outside end, they are held up and enough earth removed to allow another set being placed to support the lagging nearer the tunnel face. While practicable in rather loose ground, this method is not available in material containing boulders, and is dangerous when used in quicksand.

21. Tunneling in Running Ground or Quicksand. The several methods employed for excavating in running ground or quicksand are *wedging*, the use of *metal shields*, the *pneumatic process*, and the *freezing process*.

NOTE.—Metal shields and the pneumatic and freezing processes have been developed and used chiefly in connection with shaft sinking, and will be described in detail under that heading.

22. Wedging Method.—In some cases, it has been possible to drive through very fine quicksand by simply wedging all or most of the material out of the way by wedges driven as shown in Fig. 8. *a* are the posts of regular timber sets; *b*, the side planking; *c*, the spiling driven, as in forepoling, to support the top; *d*, the wedges; *e*, the tailing pieces; *f*, the floor; *g*, the bridging pieces; and *h*,

the cap pieces. The set of timber shown below *e* is only placed temporarily, and is removed after the spile *c* is driven forwards.

The wedges *d* are driven into the face by means of a ram made of a piece of timber swung from the roof. They simply crowd the material away from in front of the excavation; if the pressure becomes so great that they can be driven no farther, a few augur holes are bored into the face to relieve the pressure by allowing some of the material to flow into the drift. Wedges are driven into the floor with a

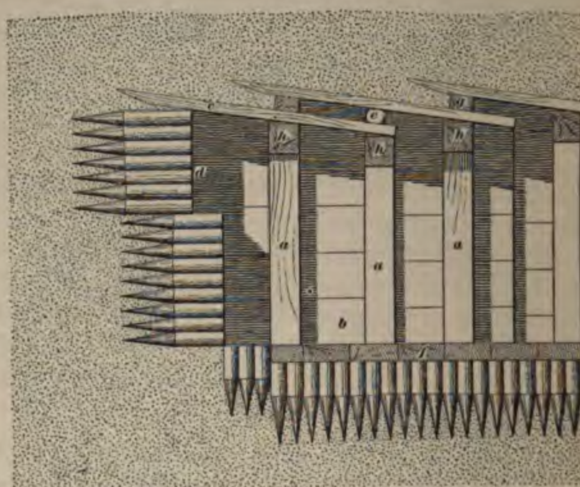

FIG. 8

mallet as fast as those in the face advance, and are ultimately covered with a plank floor *f*.

23. Tunneling in Hard Rock.—If the rock outcrops at the point selected for the location of the tunnel, a face is cleared away, and drilling and blasting begun. The work differs from that described in Arts. **10** to **18** in that no under-cutting or shearing is done; the rock is removed entirely by blasting—one or more series of holes being arranged more or less inclined to the face for this purpose. These holes should be so arranged as to permit the drills to be easily handled

give the smallest possible number of holes and the
m weight of explosives. If a single face of rock is
l, an opening, or key hole, must be made in this face
is of holes drilled at such an angle to the free face as
remove a wedge-shaped entering piece of rock; the
ng shots can then do deeper and more effective work.
nmon method of doing this is the square cut, or
in method, which is illustrated in Fig. 9; (*a*) is a front

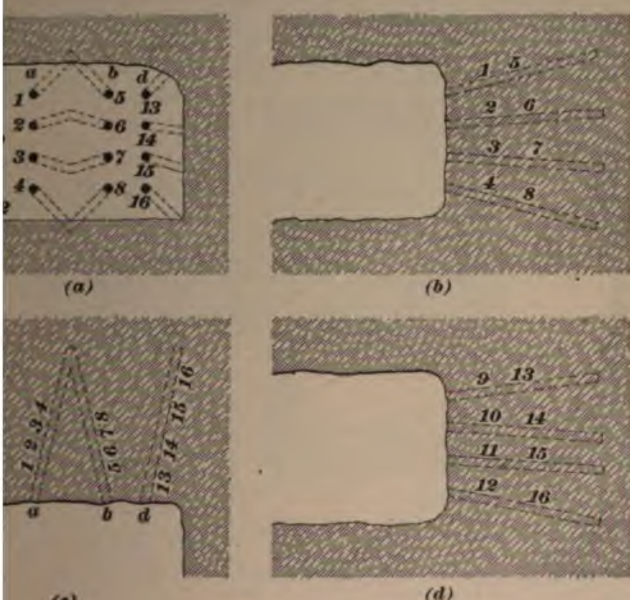

FIG. 9

the face; (*b*) is a side projection showing the direc-
the holes *1* to *8*; (*c*) is a ground plan; and (*d*) is a
on of the holes *9* to *16*. In an ordinary 7′ × 7′ mine
the holes are arranged about as shown. Rows of
b are placed on either side of the center from $2\frac{1}{2}$
et apart, the holes being about equidistant vertically,
ined to the face about as shown. Rows of side
d are placed as shown. These side holes and the
bottom holes of the center rows of holes are placed

as near the rib and the top and bottom as possible, and the more nearly the drill holes can be placed parallel to the direction of the tunnel, the straighter will the cut be made. As the number and inclination of the holes depend on the character of the rock, no definite rules can be given to cover these items—they must be learned by experience. Under ordinary conditions, however, fourteen or sixteen holes are ample for the face of a 7′ × 7′ tunnel. The two rows of center holes *1* to *8* are fired in a first volley, and the side holes *9* to *16* in a second volley. These holes are usually about 10 feet long and bring out a cut of from 2 to 3 yards in length in hard rock.

FIG. 10

It should be remembered that a rock that is hard to drill is not necessarily difficult to blast, and vice versa. Thus, a granite or some form of metamorphic rock, such as a very hard sandstone that is jointed or brittle, may be difficult to drill, but will break easily and with the use of comparatively few holes and a small amount of powder, while a clay shale, which is soft and tough and easily drilled, may be almost impossible to blast.

The entering wedge, or key cut, may be placed either in the center, at the side, or at the bottom, depending on the structure of the rock. If the rock in the face is uniform in texture and free from joints, or slips, the holes are placed symmetrically with respect to the center, as is shown in Fig. 9. They may also be arranged in circles about the key cut instead of parallel to the sides of the heading, as shown in the American method.

When a slip, or joint, occurs in the rock as at *a b*, Fig. 10, advantage may be taken of it by locating the holes for the

first volley near the slip or joint plane; but all the holes are sloped toward this plane except those needed to cut the opposite rib of the tunnel *9, 10, 11*, Fig. 10. In Fig. 10, the order of firing is, first, *1* and *2*, fired together; second, *3, 4, 5*, fired consecutively; third, *6, 7, 8*, fired consecutively; and, fourth, *9, 10, 11*, fired consecutively.

24. Removal of Material.—The removal of the material in tunneling is accomplished at first by shoveling the material to the mouth of the tunnel. As the work proceeds, wheelbarrows are used; and, finally, wooden or iron rails are laid and a small car, Fig 11, used. The material excavated from the tunnel, unless it is coal or ore that is of value, is dumped

FIG. 11

at its mouth and spread to form a nearly level surface, but with a slight grade away from the mouth and toward the dump. This will furnish track room and a convenient site for the necessary surface buildings. The cars are at first pushed out by hand, but as the face of the tunnel or drift advances, mules or horses are used and the cars hauled out in trips, or mechanical haulage is introduced.

PORTALS

25. A tunnel mouth is frequently surrounded by a frame of sawed timber and rough walls, as shown in Fig. 12 (*a*) and (*b*). Some of the more recently built plants, and particularly those where steam locomotives are used for haulage purposes, have masonry arches built over the mouth of the opening, Fig. 12 (*c*), (*d*), and (*e*); (*f*) is a concrete **portal.**

The stonework or concrete construction at the portal is carried outwards in the form of side wing walls; it is also frequently

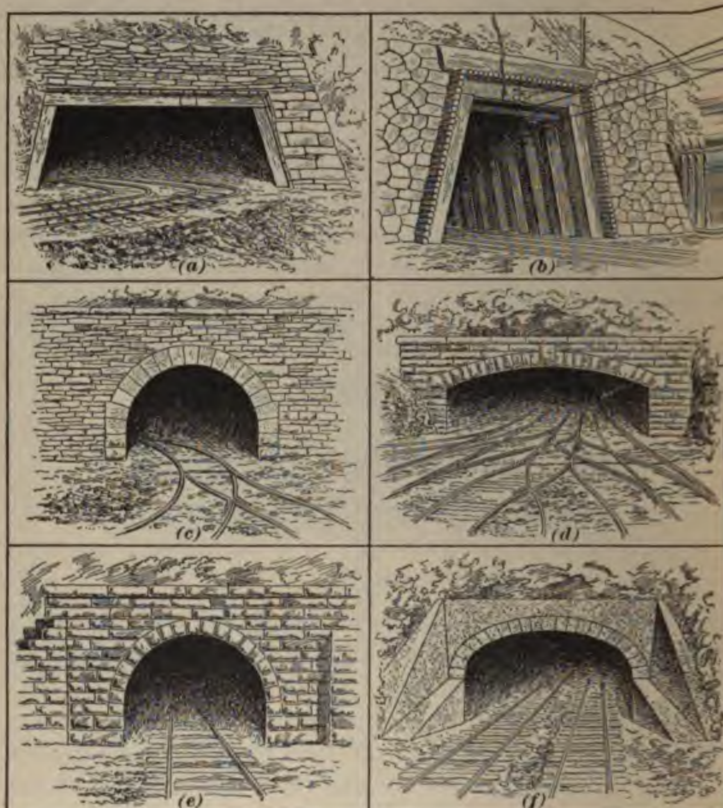

FIG. 12

carried underground to a point where a solid formation is encountered.

LINING A TUNNEL

26. It frequently happens that, owing to the scarcity of timber, or because the strength of timber is not sufficient, or for other reasons, a portion or the entire length of the tunnel is lined with stone or brick masonry.

For a hard bottom, the form of arch shown in Fig. 13 (*a*) is often used. It consists of a full semicircular arch that has its spring lying a few feet above the floor of the tunnel. The side walls may or may not be carried below the floor of the tunnel, according to the character of the floor.

For a soft bottom, the form of lining shown in Fig. 13 (*b*) is used. An inverted flat arch *a* is first laid; it is kept in

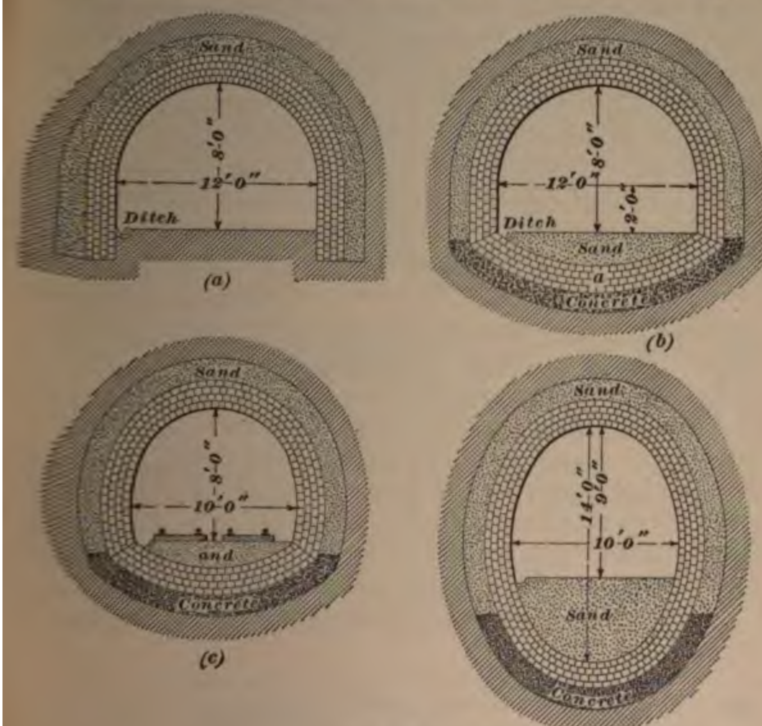

Fig. 13

advance of the side walls and the arch forming the roof of the tunnel for the purpose of allowing the work a short time for setting before the weight of the arch is placed on it. In constructing the arch forming the roof of the tunnel, wooden frames, called centers, cut to the required outline of the arch are used. These are placed from 2 to 3 feet apart,

and are covered above with short lengths of lagging on which the arch rests while being built. As each section of masonry is completed, the space behind the masonry is firmly packed with sand, ashes, cinder, slack, or other fine material in order to distribute the roof pressure evenly on the arch. A short time is given for the work to set, when the centers are taken down and moved forwards to another section.

For heavy side pressures, one of the forms of arch shown in Fig. 13 (*c*) and (*d*) is employed. In (*c*), the side walls are made the segments of a circle or an ellipse. In case the tunnel is subjected to a very heavy pressure all around, due to the soft nature of the ground, the entire section of the tunnel may be an ellipse, as shown at (*d*). Sometimes, iron templets are used instead of wood. In the building of tunnel walls, very little mortar should be used between the joints, and no old wood or material liable to decay should be left in or behind the wall.

27. Concrete for tunnel linings has proved very successful. It possesses the advantage of affording an even distribution of pressure, of being very rapidly constructed, and much less costly than masonry.

Concrete is composed of cement, sand, and crushed stone (or some substitute) mixed in such proportions as to be suitable for the purpose for which the concrete is to be used. Gravel, furnace slag, cinders, brickbats, broken slate, etc. are often substituted for the broken stone, because they are cheaper and often more readily obtained, but they do not give so good a concrete.

28. Cements are of two general kinds—*Portland cement* and *natural cement*. **Portland cements are made by mixing** certain kinds of crushed limestone and clay or other materials rich in silica, alumina, and lime, then burning the mixture to a clinker and grinding this clinker until it is reduced to a nearly impalpable powder. From the nature of this process, involving the artificial mixture of the different ingredients, the resulting product is sometimes called *artificial cement*, but is more generally known as Portland cement. Natural

cements are made by burning certain varieties of clayey limestone, in which the silica, alumina, and lime occur in proper proportions, until the CO_2 is burned off, and then grinding the clinker to a fine powder. The essential difference between these two kinds of cement is that the Portland cement is a mixture in which the ingredients are selected of such quality and in such proportions as to give the best results, while natural cement is made from much the same materials in such proportions as they occur in nature. Portland cement is much more finely ground and has greater strength than natural cement. It is better suited for use in exposed places and in places where great strength and durability are required. Natural cement, however, is adapted for use in most places where concrete is used; but as it does not possess the same strength as Portland, a larger proportion of the natural cement should be used for the same volume of concrete.

When cement is mixed with water to a stiff paste and allowed to stand a sufficient time, the paste undergoes chemical change and a solid mass results. This *setting*, as it is called, usually requires but a few hours at most. After the setting, a slower chemical action sets in, and the mass gradually gains in strength. Usually this gain of strength, or hardening, extends over a period of from 6 months to a year—sometimes even beyond this period. Chemists who have examined the chemical composition of cement do not agree as to the changes that it undergoes when it sets.

29. **In mixing concrete**, the best proportions of the ingredients to be used will depend on the character of the ingredients and the purpose for which the concrete is to be employed. For engine foundations, mine openings, tunnel and shaft linings, the following proportions will afford good results:

Using natural cement, 1 part, by measure, of cement; 2 parts, sand; 4 parts, broken stone.

Using Portland cement, 1 part, by measure, of cement; 3 parts, sand; 6 parts, broken stone.

The sand should be clean, sharp, gritty, and free from dirt or other foreign matter; when it contains any considerable amount of mud or dirt, it should be washed. The broken stone or slag should be of suitable sizes, preferably such as will pass through a ring 2 inches in diameter. Modern engineering practice does not object to the presence of the finer particles of stone in the mass. It will, consequently, not be necessary to screen the stone before using.

It is important that the concrete be thoroughly mixed, as all the spaces between the broken stone should be filled by the cement and sand. Mixing may be done by machine or by hand. Machine mixing is the better and gives more uniform results; it is also more economical where large quantities of concrete are to be used. Hand mixing may be resorted to where the quantities of concrete required are not sufficiently large to warrant the use of machinery.

In mixing concrete by hand, the sand and cement should first be mixed dry on a platform. Water is then added and the mixture is worked into a mortar. The use of too much water should be avoided; just enough to form a stiff paste is sufficient. The stone is first wetted and then added to the mortar, and the whole mass is thoroughly incorporated by turning over several times with shovels, until each stone is coated with mortar and the stones are evenly distributed through the mass. Concrete, after being mixed, should be placed in position immediately and not allowed to stand long enough to get an initial set before placing. After being placed in position, it should be well tamped with wooden or iron rammers. The tamping should be just sufficient to bring the water to the surface, and care should be taken to avoid excessive tamping, which will disturb the intimate mixture of the ingredients that is so desirable.

SLOPES

30. A slope resembles either a tunnel, a drift, or a shaft, depending on its inclination. A *flat slope* is treated, as to its size, method of driving, timbering, etc., essentially as a drift or tunnel, while a *steep slope* is treated like a shaft. It will, therefore, be necessary to point out only the few points that are peculiar to slopes and wherein practice in sinking them differs from similar work in connection with tunnels or shafts.

Blasting in a slope is more difficult than in either a shaft or a tunnel, as the rock is said to *bind*, owing to the inclination of the strata; and, in general, it may be said that more holes and more powder are required for a slope than for either a tunnel or a shaft of equal size. The amount of increase in the width of the slope pillars as the slope descends depends on the degree of pitch of the slope, which determines the thickness of cover above the slope.

The removal of the material excavated from a slope is more difficult than in drifting or tunneling, and this difficulty increases with the inclination of the slope. In starting a steep slope, as in starting a shaft, the material is removed by the use of a windlass for drawing the car up the slope, or a small portable hoisting engine may be set up when the slope has been sunk but a few yards.

The drainage of a slope is accomplished by pumps located at or near the foot, small sinking pumps placed on trucks being generally used. In order not to be obliged to move a large pump too often while sinking, inspirators, which are easily moved as the work advances, are sometimes used at the slope bottom to throw the water up to the pump station.

The *timbering* of a slope differs from that of a drift or tunnel in the manner of setting the posts, which, in a slope, are *underset* or made to lean up the pitch from a normal position in the seam, or from a position perpendicular to the plane of stratification. The amount the post is underset

and the manner of undersetting vary with the inclination of the seam.

31. Safety Appliances.—The necessity of safety appliances increases with the inclination of the slope. *Refuge*, or *shelter*, *holes* for the safety of the men engaged in the slope should be made along the slope; in some states, they are required by law, owing to the liability to accident to men by being caught and squeezed between the rib and a trip of cars, or by the breaking of the hoisting rope or car couplings, or the possibility of cars descending the incline before being attached to the rope.

Safety blocks are necessary at the knuckle or the head of all inclines, and in some states are required by law. They consist of blocks so arranged as to prevent cars descending the incline before all is ready and the signal given. They may be operated at the knuckle, by the topman, or headman, or from the engine room. The block is so arranged, by means of a spring pole, weight, or spring, that the ascending cars will pass it without difficulty, but it will automatically return to its place when the car has passed. At some slopes, safety blocks are arranged at regular intervals along the incline, for the purpose of preventing the descent of the car or cars if the hoisting rope should break.

A *derailing switch* is sometimes employed either instead of or in conjunction with a safety block. This is an automatic spring-pole switch similar to the switch used for turnouts in mine haulage, and permits the ascending cars to pass on the main track, but a descending car will be switched off on a side track. The derailing switch, like the safety block, may be operated at the knuckle or from the engine room, as desired.

The *safety dog* is a heavy trailing bar attached or coupled to the drawbar at the rear of the ascending car or trip of cars and allowed to drag along the track as the car proceeds up the incline. The lower end, which drags on the ground, may be either pointed or split. If the hoisting rope breaks, the weight of the car on the incline forces the dog into the floor and the cars are either stopped or derailed.

SHAFTS

INTRODUCTION

32. Form of Shaft.—A shaft may be either *circular*, *elliptic*, *polygonal*, or *rectangular*. The first three forms are better adapted to withstand pressure than the rectangular, but they are more difficult to timber, and there is always a considerable area of the cross-section that is not available for hoisting. Such shafts are usually lined with brick, masonry, concrete, or metal instead of timber and are preferred in many European countries, while rectangular shafts are generally used in the United States. The practice of lining shafts with concrete is growing rapidly in the United States and many of these have their sides and ends made as arcs of circles, so as to present an arch to the side and end pressures. The approximate section of the shaft is then elliptical. Rectangular shafts are either oblong or square, the former being the usual form for a hoisting shaft, while the latter is often used for a small prospect shaft, or for a second opening to be used as an escape shaft or an air-shaft. Rectangular shafts are usually not lined with masonry on account of the danger of the walls bulging, owing to the pressure of the strata behind them, although a number of rectangular shafts have been lined with concrete; timber of sufficient size is generally used for the lining in these shafts, and when bulging takes place, any of these timbers can be taken out and replaced by others after the trouble has been removed.

33. Compartments.—A shaft is usually divided into two or more compartments, either by buntons or cross-timbers placed one above another and spaced from 6 to 8 feet apart, or by solid partitions formed of 3-inch or 4-inch

planking. If there are but two compartments, both of them may be hoistways or one may be a hoistway and the other a pumpway and ladderway. If there are three compartments, two of them are hoistways, and the third, and smaller, compartment, which is at the end of the shaft, is used for a manway and pumpway and for carrying steam or compressed-air pipes or electric wires into the mine.

34. Size of Shafts.—The size of a shaft depends on the use for which it is intended and is determined by the hoisting, drainage, and ventilating conditions at the given mine. Before commencing to sink, a careful estimate should be made as to the size required for all future developments of the mine. Nothing is saved in sinking a shaft of too small dimensions, for the work of excavation is more easily accomplished in a large shaft, while the serious annoyance and limitations of a small shaft, and the great expense of enlarging a shaft already sunk, warrant a shaft of generous size. A *tight shaft* is one in which there is but little space between the curbing and the edge of the cage. In such a shaft, the cage acts like the piston of an air pump, moving the doors in the mine, and causing a general disarrangement of ventilation. In such a shaft, also, a very small amount of ice will interfere with hoisting.

Shafts for coal mines vary in size from 5 ft. × 10 ft. to 12 ft. × 54 ft. inside the timbers. Shafts at metal mines vary in size from 5 ft. × 5 ft. to 15 ft. × 25 ft. Table I gives interesting data about some of the leading American shafts.

35. Calculation of Size of Hoisting Shaft.—The size of a hoisting shaft is determined by the output of material required, the depth of the shaft, the speed of hoisting, the size of the mine car, and the number of cars hoisted at one time. The speed of hoisting is commonly understood to mean the maximum speed at which the cage moves during the hoist. This speed and the time lost in starting and stopping vary with the depth of the shaft. In general, the deeper the shaft the greater is the speed of hoisting allowed, and the

TABLE OF

Name	Location	Material Mined	No. of
No. 5 shaft	Wilkes-Barre, Pa.	Anthracite	
Hazleton shaft	Hazleton, Pa.	Anthracite	
Exeter red ash	Exeter Boro., Luzerne Co., Pa.	Anthracite	
Leith mine	Uniontown, Pa.	Bituminous	
Chicago, Wilmington & Vermilion Coal Co. .	Thayer, Ill.	Bituminous	
Madison Coal Co., St. Louis, Mo.	Divernon, Ill.	Bituminous	
Gilberton water shaft .	Gilberton, Pa.	Hoisting water and men	
General type	Pa. Bituminous Region	Bituminous	
Centennial Eureka . . .	Eureka, Utah	Gold, silver, copper, lead	
Ontario	Park City, Utah	Silver	
Red Jacket	Calumet, Mich.	Copper	
Tamarack	Tamarack, Mich.	Copper	
Anaconda	Butte, Mont.	Copper	
Butte and Boston . .	Butte, Mont.	Copper	
Hamilton	Iron Mountain, Mich.	Iron	
Salisbury	Ishpeming, Mich.	Iron	
Fayal Iron Co.	Eveleth, Minn.	Iron	
Consolidated California & Virginia Mining Co.	Virginia City, Nev.	Gold, silver	
Virginius	Revenue Mt., Colo.		
Isabella	Cripple Creek, Colo.	Gold	
Average for large mines in	Colorado		
Parker shaft	Franklin Furnace, N. J.	Zinc	
General type	Joplin, Mo.	Zinc	

*Depth completed, 1,150 feet.
†In the clear.

greater the speed the greater is the proportional loss due to starting and stopping the engine. This loss of time in starting and stopping varies from 3 to 10 seconds. The time consumed, between hoists, in caging and uncaging cars varies according to the style of equipment and the manner of caging cars employed. For ordinary conditions, it can safely be assumed to be from 5 to 15 seconds; and this amount added to the allowance made for the loss of time in starting and stopping the engine, or from 3 to 10 seconds, makes a total allowance between hoists of from 8 to 25 seconds.

The speeds of hoisting for shafts of different depths are given in Table II.

TABLE II

Depth of Shaft	Speed of Hoisting Feet Per Second
100	10 to 15
200	15 to 20
300	20 to 25
400	20 to 35
500	25 to 40
600	30 to 50
800	30 to 50
1,000	30 to 50

In estimating the output, an allowance of from 5 to 10 per cent., according to the character of the hoisting plant and other conditions, is made for delays. Thus, if hoisting is performed in 10 hours and if a delay of 5 per cent. is allowed, the net time of hoisting will be 95 per cent. of 10 hours, or $.95 (10 \times 60) = 570$ minutes. The total daily output divided by the net time of hoisting, in minutes, gives the required output per minute. The depth of the shaft, in feet, divided by the speed of hoisting, in feet per second, gives the time per hoist, in seconds, approximately, though it does not take account of the time lost in accelerating the engine in starting. The time per hoist plus the time for caging and uncaging gives the total time for each trip of the cage, in seconds. Then 60 seconds divided by the time per trip gives the number of trips per minute. The output per minute divided by the trips per minute gives the weight of material hoisted at each trip of the cage. If one car is hoisted at a time, this will give the capacity of the car; if two cars are hoisted at a time, the capacity of the car is obtained

by dividing the weight hoisted by two, etc. The capacity of a car, in cubic feet, is found by dividing the weight of material, in pounds, carried by the car by the weight of a cubic foot of the material hoisted. A cubic foot of any solid material equals the weight of a cubic foot of water (62.5 pounds) multiplied by the specific gravity of the material. Table III shows the weight, per cubic foot, of anthracite and bituminous coals of different specific gravities solid and broken, the latter being given for both loose and moderately shaken coal. Coal, when broken, occupies about 1.5 the space occupied by the same amount when solid; the weight of the broken coal is, therefore, about two-thirds that of the solid coal.

TABLE III

Kind	Specific Gravity	Weight, Pounds Per Cubic Foot		
		Solid	Broken	
			Loose	Moderately Shaken
Anthracite	1.4	87.50	49 to 54	53 to 58
	1.5	93.75	52 to 58	56 to 62
	1.6	100.00	55 to 61	60 to 67
	1.7	106.25	59 to 66	64 to 70
Bituminous	1.2	75.00	41 to 46	45 to 50
	1.3	81.25	45 to 50	49 to 54
	1.4	87.50	49 to 54	53 to 58
	1.5	93.75	52 to 58	56 to 62

36. **The width of the shaft** depends upon the size [illegible] car to be hoisted. The length of the box of a mine car [illegible] determined by the formula

$$l = \frac{c}{b\,d}$$

in which l = inside length, in feet;
c = capacity, in cubic feet;
b = average breadth, in feet;
d = depth, in feet, including the topping.

To the inside length of the car calculated by this formula, must be added the thickness of the end planks, each end being from 1 to 2 inches thick, and the length of the bumpers at each end of the car, from 4 to 10 inches, according to the style of car used, in order to obtain the length of car, out to out of bumpers. To this must be added 6 to 8 inches for clearance between each end of the car and the cage, and 6 to 9 inches more for clearance between each end of the cage and the shaft timbers, to obtain the width of the shaft in the clear.

Cars, for use in coal mines, vary from 4 to 6 feet in width, from 5 to 10 feet in length, and from 2 to 5 feet in height. Their capacities vary from 1,000 to 8,000 pounds of coal and their weight from 500 to 4,000 pounds. Cars for use at ore mines vary from 2 to 3 feet in width, from 3 to 6 feet in length, and are about 3 feet high. They vary in capacity from 1 to 2 tons and in weight from 600 to 1,500 pounds.

EXAMPLE.—Find the width of a shaft required for hoisting an output of 1,200 tons of bituminous coal per day of 8 hours, from a depth of 500 feet; the seam is 5 feet 6 inches thick, and has a good roof and floor; the specific gravity of the coal is 1.3.

SOLUTION.—Allowing 5 per cent. for delays, we have, for the net time of hoisting, $.95(8 \times 60) = 456$ min.; and for the output

$$\frac{1,200 \times 2,000}{456} = \text{say, } 5,264 \text{ lb. per min.}$$

Referring to Table II, we find that the speed of hoisting in a shaft 500 ft. deep varies from 25 to 40 ft. per sec. Assuming 25 ft. per sec., the time of hoisting one trip is $\frac{500}{25} = 20$ sec. Assuming 10 sec. for the time of caging and uncaging, the total time for each hoist is $20 + 10 = 30$ sec. Then $\frac{60 \text{ sec.}}{30} = 2$ hoists per min., and if one car is hoisted at a time, the weight of material per hoist is $\frac{5264}{2} = 2,632$ lb. of coal. In Table III, the weight of bituminous coal having a specific gravity of 1.3 is given as varying from 45 to 50 lb. per cu. ft., when broken loose). For the ordinary mine run, assume 48 lb. per cu. ft.; then the capacity of a car is $\frac{2632}{48}$ = about 55 cu. ft.

Assuming that the depth of coal on the car, including topping, is 30 in. ($2\frac{1}{2}$ ft.) and the inside width 40 in. ($3\frac{1}{3}$ ft.), then the inside length is

$$l = \frac{c}{b\,d} = \frac{55}{3\frac{1}{3} \times 2\frac{1}{2}}; \frac{55}{\frac{10}{3} \times \frac{5}{2}} = \frac{55 \times 6}{50} = 6.6 \text{ ft. (6 ft. 8 in.)}$$

Adding, to the inside length, 4 in. for the ends of the car and 12 in. for bumpers, the total length of car will be 8 ft. Then adding 3 in. clearance, between each end of the car and the cage, and 9 in. at each end for shaft clearance, the required width of the shaft is 10 ft. in the clear. Ans.

37. **The length of the shaft** must ordinarily be such as to provide for two hoistways, and a pumpway or manway. The width of each hoisting compartment should be such as to give at least 6 inches of clearance between the greatest width of the car, out to out, and the guides. Allowance must be made also for the width of buntons separating the two hoistways, the thickness of the guides, and the width of

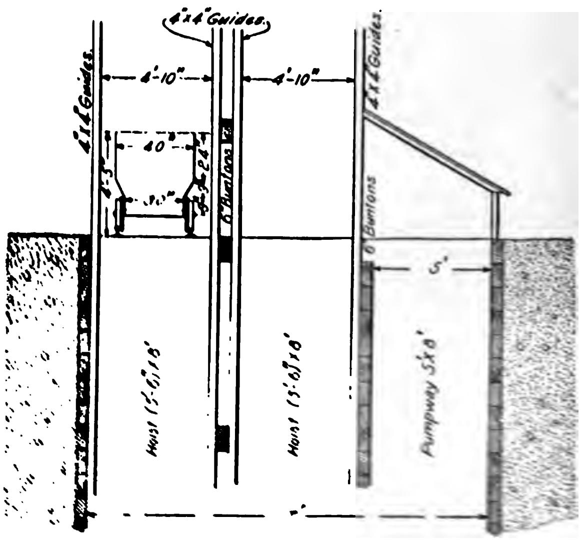

FIG. 24

buntons separating the hoisting compartment from the pumpway. According to the size and depth of the shaft and the character of the strata, the thickness of the buntons will vary from 6 to 12 inches. The size of the guides often employed in hoisting shafts is 4 in. × 4 in., and the guides are commonly bolted to the buntons.

[illegible] the width of the car is shown as 40 inches, [illegible] the clear width between the guides in each

s 4 feet 10 inches, giving a clearance of 9 inches de of the car. The size of the guides is 4 in. naking the total width of each hoistway 5 feet The buntons shown in the figure are 6 inches wide mpway 5 feet wide, making the total length of the the clear, 17 feet. The width of the hoistway ds on the number and size of cars hoisted at one whether two cars are placed side by side on the ne above the other on a double-deck cage.

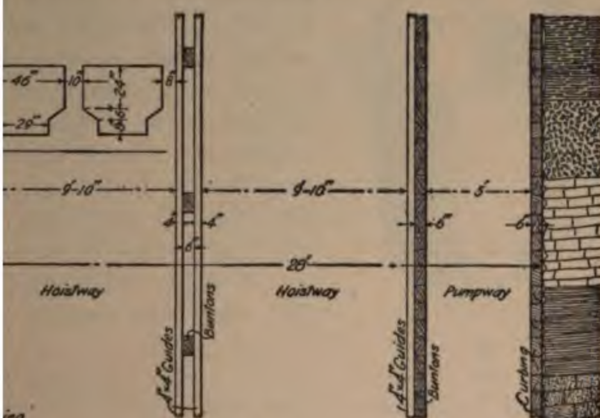

FIG. 15

shows the cross-section of a shaft where two cars d side by side on the cage. The entire length of n the clear, including hoistways and pumpways, is ving two hoistways each 9 feet 10 inches in the veen guides, and a pumpway 5 feet in the clear. s are each 4 inches and the buntons 6 inches wide; of the cars is 46 inches, giving a clearance of n each side, and 10 inches between the cars. This large shaft, being capable of accommodating an between 3,000 and 4,000 tons per day.

SINKING TOOLS AND APPLIANCES

38. A large number of tools and appliances are required in sinking, but the most of them are used only in special cases, where the conditions of the strata make them necessary.


Fig. 16

The **buckets** used for hoisting the material excavated in sinking are usually made of boiler iron or steel; two of the many shapes are shown in Figs. 16 and 17. The bucket shown in Fig. 16 is supported from chains attached by a spring hook to ears on its sides and is dumped by being tilted by means of the handle shown. These buckets are from 2½ to 3 feet in height, about 27 inches in diameter at the top, 18 inches in diameter at the bottom, and hold about 6 cubic feet. They weigh about 150 pounds.

The form of bucket shown in Fig. 17 varies from 16 to 28 inches in diameter at the top, from 14 to 28 inches in diameter at the bottom, and from 26 to 38 inches in height; it varies in weight from 180 to 470 pounds and in capacity from 2½ to 14 cubic feet. The bail *a* is attached at a point below the center of gravity of the bucket so that the tendency of the bucket is to turn over and empty itself. To prevent this while hoisting, a short pin *b* is riveted to the side and an ordinary chain link sliding on the bail is slipped over it. While these buckets are easily dumped, numerous accidents have been caused by their overturning in the shaft while hoisting men or material.

Fig. 17

A bucket is often made by sawing an oil barrel just above the second hoop from the top, and riveting to the lower part

substantial eyes for securing the bail to the bucket. The hoisting rope is usually attached to the bail of the sinking bucket by a special hook provided with a clip or extra link and pin for securing the hook fastening while the bucket is being hoisted, as shown in Fig. 18 (*a*); or two hooks are arranged with a drop link, as shown in Fig. 18 (*b*). At times, bridle chains are used, the hoisting rope being attached permanently

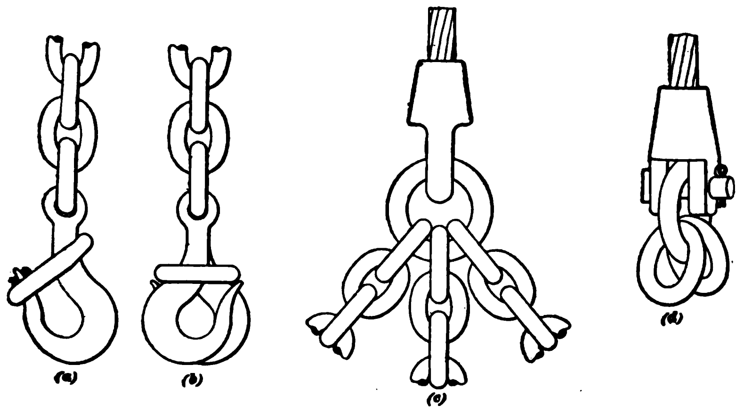

FIG. 18

to the bridle chain by a socket, as in Fig. 18 (*c*), or a clevis, as in Fig. 18 (*d*). Boxes with drop bottoms are sometimes used instead of buckets for hoisting, and those using them claim a greater speed in the removal of material than with buckets; they are, however, dangerous, on account of premature opening of the bottom during hoisting, and sinkers should not be allowed to ride in them.

39. Guides for Buckets.—When the bucket has a tendency to twist in hoisting from a deep shaft, the difficulty may be overcome by the use of guides and some form of sinking yoke, a simple form of which is shown in Fig. 19. The guide ropes *c* are either coiled on a drum and lowered as the sinking proceeds, or are hung from the timbers across the top of the shaft. Large weights are attached to the lower ends to keep them steady. The hoisting rope passes through a hole in the center of the *rider*, which is an iron frame

consisting of two legs joined together by a cross-
encircling the two rope guides loosely at the four poin
the bottom of the shaft timbers stop-blocks *h* hold t
while the bucket goes to the bottom of the shaft, thus
the rider and the guide ropes out of the way of the
As the bucket is hoisted, the rope socket picks up t
when it is reached. Considerable time is lost in st

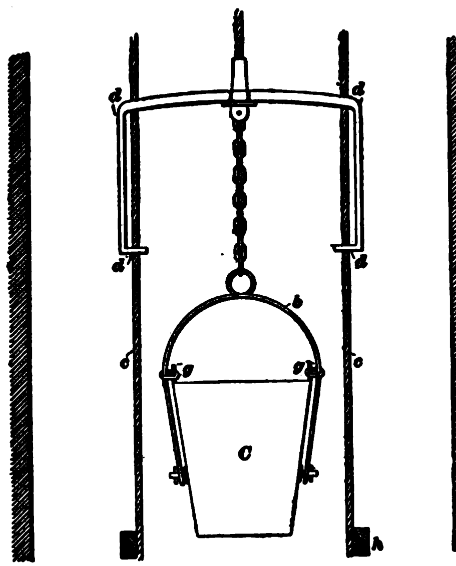

Fig. 19

the bucket l
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rider is use

Fig. 20 s
form of yo
slides on gu
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the cross-pie
yoke, there
ferrules t
which the
passes, the
hole being c
receive the
the rope soc
the bottom o
bering, two
are bolted
side of the guides to prevent the yoke from descendir
the timbers, while the bucket passes down to the bc
the shaft.

In using yokes or crossheads, great care should l
to have the guides parallel and with good joints, f
accidents have occurred from the crosshead sticking ar
ing in the shaft, while the bucket continued to go dc
the crosshead jars loose after the bucket has gone 50 or
below, it falls on the bucket and may carry it to the
This is more likely to occur in lowering men tha
lowering the empty bucket, for in the latter case th
ing is quickly done, taking the crosshead past the tigl

Cages are sometimes used in sinking, in which case false guides must be put in from the lower end of the permanent timber to the bottom of the shaft. As these guides must be removed before each blast, and then replaced, the use of cages is not generally considered with much favor.

40. Dumping the Buckets.—At the top, the bucket may be dumped automatically by placing a catch hook so that it engages one side of the bucket rim and tips it as the hoisting is continued, dumping the material either into a chute or into a car. Any method of dumping the bucket while over the shaft is dangerous, as small stones may fall down the shaft through the hole provided for the hoisting rope. It also throws a considerable strain on the head-frame, hoisting gear, and rope; and if an accident occurs to the hoisting rope while dumping, the bucket and its load may fall on the shaft cover with sufficient force to break through and fall to the bottom. A better arrangement is to swing the bucket clear of the shaft by means of a short snatch rope that hangs from a point in the top of the head-frame and at one side of the shaft opening. The hook is quickly put into the bail of the bucket as it comes up, and when slack is given by the engineer, the bucket is swung clear of the shaft and dumped or transferred to a car.

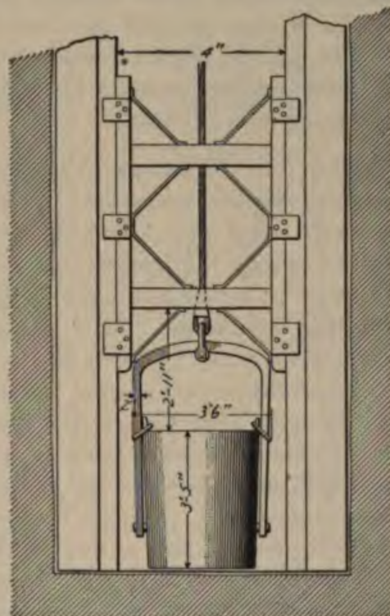


FIG. 20

Several buckets are often used for hoisting material, and as soon as the bucket has passed through the shaft opening,

a larry or truck running on a broad track that spans the shaft opening is pushed underneath it, the bucket is lowered on to the larry, the hooks are snapped, and an empty bucket attached in its stead. The larry is then moved to one side and the empty bucket lowered into the shaft.

The **larry,** or truck, is a low flat car similar to that shown in Fig. 11 but without sides. An old railroad hand car that has had its axles made to fit the gauge of the rails laid across the shaft is often used.

41. The **hoisting engine** used in connection with the sinking is either a special engine that forms part of the shaft sinker's outfit and can easily be moved from place to place, or any engine that can be readily had and used until the shaft or slope is finished, when it is dismantled and disposed of to the best advantage. Such engines can sometimes be rented for a daily rental of $1 or $2.

A second-motion engine is safer for sinking purposes than a first-motion engine, as it is not so quick and positive in its movement of cages or buckets and the engine can be run rapidly with less danger to the sinkers. A good hoisting engine should be able to pick the bucket off the bottom at any time, without getting stuck on center, or having to run back for slack.

The engines for sinking are usually placed on a temporary foundation made of heavy timbers. The tower backstays are sometimes used as part of this foundation, though this is not good practice, as they may move.

42. A **portable boiler** of the locomotive type is generally used, and the engineer frequently does his own firing. When a second shaft is sunk within 300 or 400 feet of the main hoisting shaft, steam is either sent direct to the sinking engine at the second shaft through a pipe large enough to avoid condensation, or the steam is passed through a boiler at the escape shaft and any excess of water there taken out before steam is used. The auxiliary boiler at the second shaft is not fired and is only used as a separator for the water that is blown off from time to time, thus allowing the use of smaller steam pipes.

43. The sinking head-frame is generally designed for nporary use only, though when an air-shaft or escape ıft is supplied with cages or a bucket for hoisting, the king tower, or head-frame, may be left in place after the ıft has been sunk. It is usually built of 8″ × 8″ or

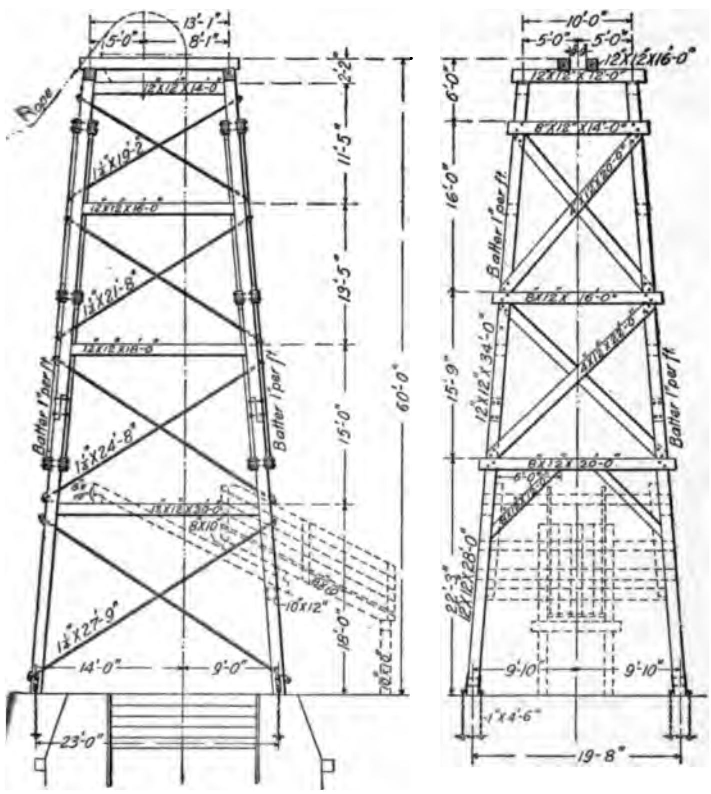


FIG. 21

″ × 12″ pine timbers that are mortised and cross-braced, tied, with heavy iron rods. Fig. 21 shows an unusual m of frame that was used in sinking one of the largest afts ever sunk; it was 12 ft. × 54 ft. in cross-section. Sinking frames are sometimes built of 2½″ × 2½″ angle n; in some cases, these are cheaper than those made of

timber, as they are put together with bolts and rivets, which can be easily removed with less damage to the parts than in the case of a timber frame put together with mortise and tenon. Railroad rails are laid across the shorter dimension of the shaft mouth midway of its length for a "larry" track.

A single sheave from 6 to 8 feet in diameter rests on the tower, usually at a height of from 20 to 30 feet above the ground, so that the bucket will hang in the center of the shorter dimension of the shaft. Instead of using a head-

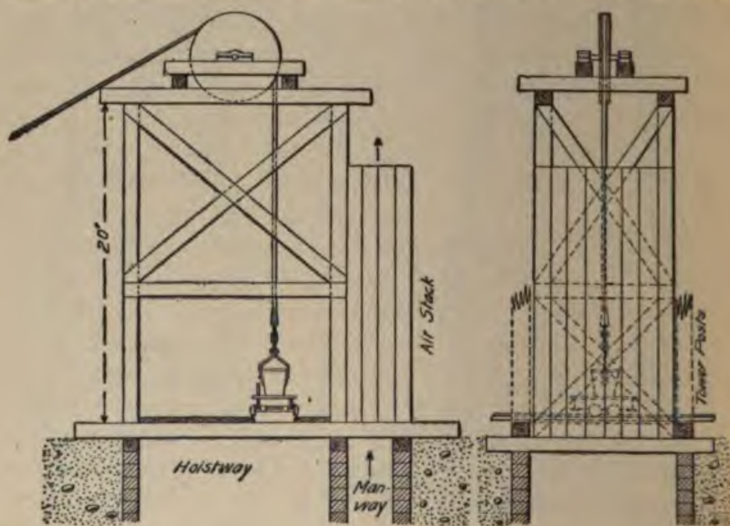


FIG. 22

frame, a derrick is frequently used, at least until after the shaft has been sunk through the surface wash.

In order that the work of sinking may not interfere with the progress of the permanent work about and over the shaft, such as the erection of the main tower, or head-frame, and the building of the foundations for the permanent hoisting engine, buildings, etc., the temporary hoisting engine should be located at one end of the shaft (at the end opposite the manway if possible), as shown in Fig. 22, which gives a side and an end view of a temporary head-frame. This shaft is to be a three-compartment shaft, having two hoisting

compartments and a manway. The manway is divided from the hoisting compartments by a close partition of heavy timber. The buntons separating the two hoistways are put in later, or when the sinking is completed. In the side view, Fig. 22, the head-frame is shown set on the cross-sills, just inside the main sills, so as not to interfere with the erection of the outer posts of the permanent head-frame. By this arrangement, the hoisting of the excavated material may continue uninterrupted while the permanent head-frame and buildings are being erected.

The waste material hoisted out of the shaft is dumped about the shaft frame and about the foundations of the permanent machinery and a level surface is thus gradually built up. If the ground slopes away rapidly from the shaft, it may be necessary to build a trestle for the larry track. A smaller car is sometimes placed on a larger truck and run out on a trestle at right angles to the main dumping trestle.

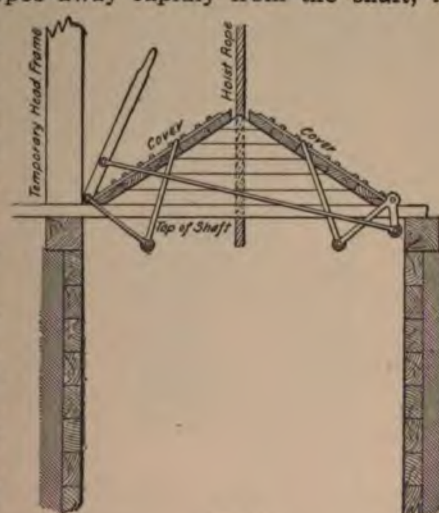


Fig. 23

44. Shaft Coverings.—In order to prevent material falling into the shaft, the top should be covered with 3-inch or 4-inch plank, excepting the portion that must be left open for the passage of the hoisting bucket. This opening may be simply covered by the larry, as shown in Fig. 22; but it is better to have a pair of doors meeting in the middle and closing down flat, or as shown in Fig. 23. In the raised position, they rest on a triangular boxing at each end and may be so arranged that the ascending bucket will open the doors for its own passage, while they are closed by means of weights

not shown; or the doors may be opened and closed by the levers shown in the figure. The balance weights should not hang inside the shaft as is sometimes done, for if the ropes break they will drop to the bottom. When the doors are closed, the hoisting rope passes through a small hole cut in the two edges of the doors.

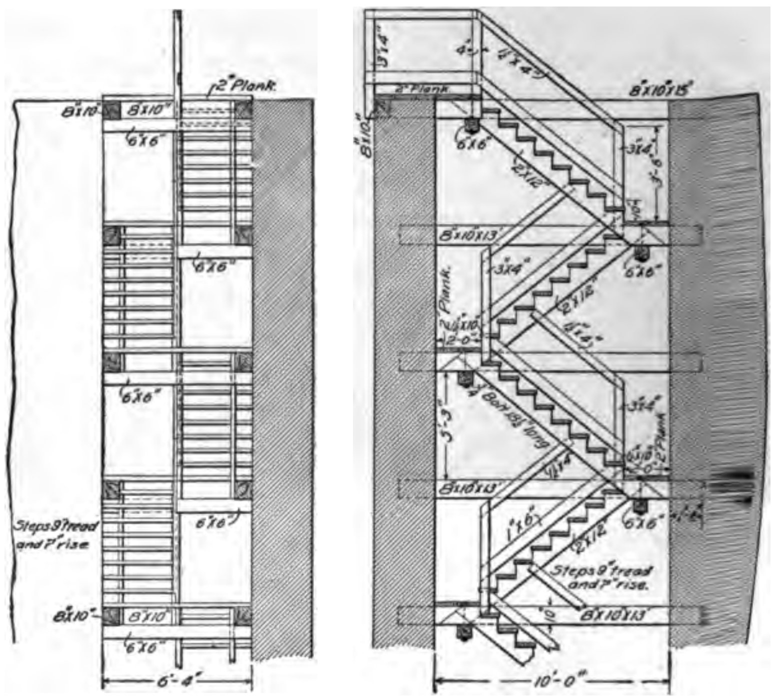


Fig. 24

45. Ventilation.—An air-shaft of boards is erected over the manway at the surface; this serves the double purpose of protecting the manway and ventilating the shaft, as a natural current is produced in the shaft. The partition separating the manway from the hoistway should be kept close to the bottom of the excavation. If this does not provide sufficient ventilation, a steam jet or small blower, such as is used in a blacksmith's forge, may be used.

. **Manway or Pumpway.**—When the small com-
ient at the end of the shaft is used as a manway, it is ped with stairways, Fig. 24, inclined ladders, Fig. 25 (*a*) *b*), or vertical ladders. The mining law in some states des that such stairs or ladders shall not have an inclination er than 60°, and that proper landings shall be made at p and bottom of each flight of stairs. Vertical ladders articularly dangerous. The ladders are sometimes ged one above another, with a suitable staging or plat-

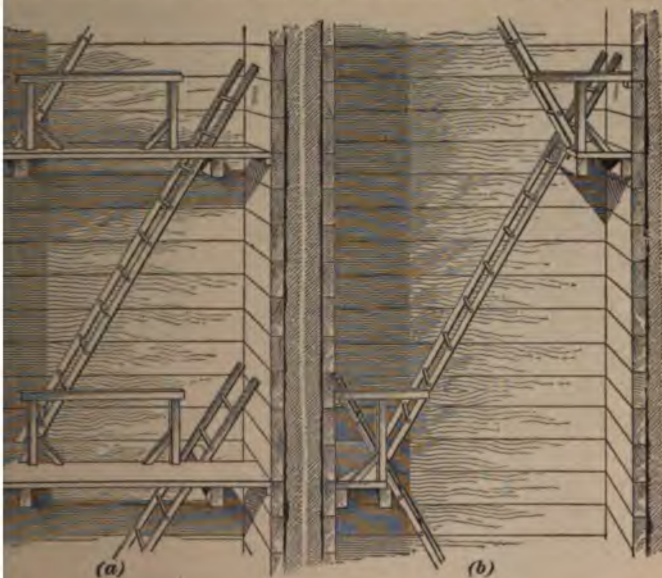


FIG. 25

connecting the top of each ladder with the foot of the ladder above, all the ladders being inclined in the same tion, Fig. 25 (*a*); sometimes they zigzag across the the foot of one ladder being placed alongside the top e ladder below it, Fig. 25 (*b*).

. **Lighting.**—As sinking operations are frequently nuous, day and night, some good form of artificial light ential at the top as well as at the bottom of the shaft; rproofed incandescent lamps are most satisfactory. A

group of these protected by a metal basket forms by far the most convenient method of lighting the bottom, as they give ample illumination and can be easily hoisted out of the way during blasting and can also be easily run up and down the shaft for an examination of the timbering. Electric light do not load the air with the impure fumes that come from the ordinary miner's lamp, especially where kerosene oil i burned. The water dripping down the shaft causes an incrus tation to form on the wick of a miner's lamp, which mu be removed constan ly in order to mai tain a good ligh The top of the sha should be provid with a strong a steady light, and f this purpose a p tected lamp or lante with a good reflec should be used.

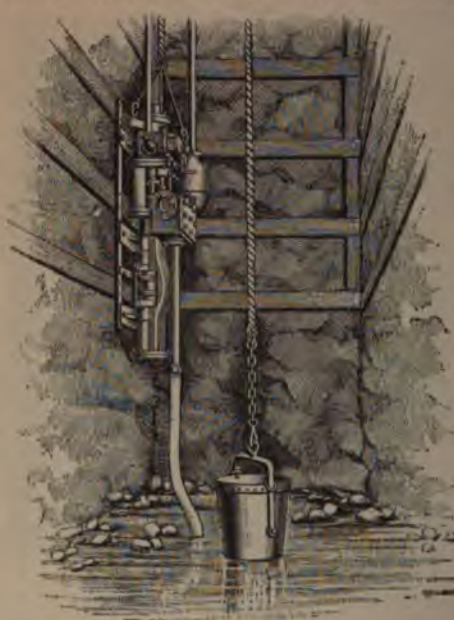


Fig. 26

48. Drainag Surface water is k out of the shaft banking about shaft sill the c and other mate taken out during t sinking. The wat pumped or hoiste from the shaft is carried away in tight wooden troughs tha lead in the direction in which the surface dips, and exten far enough from the shaft to prevent the water from returning Water within a comparatively short distance from the surfac can be drained from the shaft by sinking a well or sma shaft adjacent to the main shaft. During the sinking, hole, or sump, is excavated at one end or in the center of th shaft somewhat in advance of the general work. The wate

is either bailed out of this hole and hoisted in buckets, or a sinking pump of special form is employed. These pumps may be hung by hooks from the timbering, Fig. 26, at any point or simply hung by ropes, and may be hoisted and lowered as desired. Instead of a special sinking pump, a small horizontal pump of ordinary pattern is often set up on a temporary staging, which is moved downwards as the work advances. Either of these pumps is connected with the steam and water pipes in the manway by short lengths of wire-wound rubber hose.

WORK OF SINKING

PREPARATION

49. The work of preparation is of the first importance in the sinking of a shaft. All materials and appliances that are liable to be required, or at least a sufficient supply for immediate need, should be on the ground and in readiness for use before the work of excavation is begun. Prospect holes or shafts in the vicinity will make known the character of the strata to be penetrated, and will determine the probable need in respect to materials and appliances. In the process of sinking, much delay and damage are frequently occasioned because the material required is not on the ground; the need is often urgent and any delay may cause the loss of the shaft.

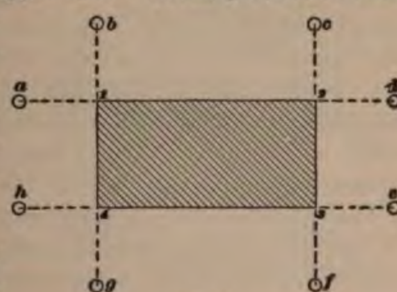


Fig. 27

50. Position of Shaft.—A suitable site for the shaft having been selected and a plan of the surface tracks and connections having been submitted and approved by the railroad company, the exact position is staked out by driving eight stakes *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h* in line with the ends and sides of the shaft and outside the area likely to be disturbed by the

sinking operation, as shown in Fig. 27. These stakes are located with a transit so that *a d* and *h e* are parallel and distant from each other a distance equal to the width of the shaft. *b g* and *c f* are parallel to each other and perpendicular to *a d* and *h e* and distant from each other a distance equal to the length of the shaft. If cords be stretched between *a d*, *h e*, *b g*, and *c f*, their intersections *1, 2, 3, 4* give the four corners of the shaft. By measuring the distances *a 1*, *b 1*, *c 2*, *d 2*, *e 3*, *f 3*, *g 4*, *h 4*, the points *1, 2, 3, 4* can be checked at any time by measurement from any two of the permanent stakes, or they can be located by sighting with the transit and measuring from any of the fixed stakes.

If the loading tracks are near the shaft, the long side of the shaft should be made, as nearly as possible, parallel to these tracks. If the seam to be developed is inclined, the long side should be, as nearly as possible, parallel to the line of dip of the seam.

FIG. 28

51. Shaft Templet, or Sill.—After the shaft has been staked out, shallow trenches are dug on each end line in which are laid the *end sills*, or *cross-sills*, which extend from 6 to 8 feet outside the shaft line on each side. Similar *side sills*, or *main sills*, are then laid across the end sills; these extend from 4 to 5 feet beyond each end line, as shown in Fig. 28.

These timbers are usually of carefully selected 12″ × 12″ or 12″ × 16″ oak. Square boxings from ½ inch to 2 inches deep are cut in the upper faces of the end timbers and in the lower faces of the side timbers and a drift pin inserted at each corner to pin the sills together. The length of the long timbers between the notches, or boxing, is equal to the clear length of the shaft, and that of the cross-timbers between the notches is equal to the clear width of the shaft, so that these timbers form a templet for the size of the shaft

in the clear for all future excavation. When these timbers are laid in position, instead of being laid in trenches or on the surface of the ground, the sills are frequently raised and clay dumped about them to a sufficient height to prevent surface water running into the shaft. The timbers thus raised are supported on blocking and carefully leveled and squared. The work of sinking and the methods of timbering vary greatly according to the character of the ground and will therefore be treated under separate headings.

SINKING THROUGH GROUND THAT DOES NOT RUN

52. Sinking Through Soft Ground or Loose Rock. The excavation is started with pick and shovel by throwing the material from within the timber frame or sills. The earth is excavated a sufficient distance from the face of the timbers all around the shaft to allow the face of the shaft lining to be set flush with the face of the sills. The *face* of the timbers is the exposed surface on the inside forming the face of the shaft when timbered; the surface against the strata is called the *back* of the timbers. The excavation is carried down without timbers to support the side and end walls, as far as is considered safe, when the work is squared and the curbing, or shaft lining, put in place. The depth thus excavated without supporting timbers will depend on the nature of the ground and will vary from 6 to 20 feet. With a long-handled shovel, a man can generally throw the dirt to the surface from a depth of 10 feet, after which a temporary staging must be erected, Fig. 29, on which the dirt is thrown and thence to the

FIG. 29

surface. The pick used is the ordinary heavy dirt pick wi wide point, while the shovel is the round-pointed D-handl shovel; when the material is thrown to a considerable heigh a long-handled shovel is used. Wedges may be employ for wedging loose sandstone and slate from the bottom a for trimming the sides and ends of the excavation, but powder is used. The walls and corners of the shaft a neatly trimmed and carefully watched for any sign of yiel ing, as the excavation must not be carried unsupported enough to cause any caving, bulging, or weakening of t ground about the head of the shaft.

As it is important that the shaft be kept vertical, a plum line *c*, Fig. 30, is usually suspended from each corner of rectangular shaft, or from the center of a circular sha It may be hung from block *b*, spiked in the c ner of the sills, or from cast-iron plate about 1 f square screwed on one the sills at one corner, plumb-line passing throu a small hole in the pla It is arranged so as to ha 4 or 6 inches from the face of the shaft timbers. In ex vating the earth, or in setting the shaft lining, measu ment is made from these lines, allowing, when excavati for the thickness of the walling or timbers forming the sh lining. Thus, if the plumb-lines are hung 4 inches from face of the shaft, and the thickness of the shaft lining 6 inches, a measurement of 10 inches will clear the timbe It is customary, however, to allow about 2 inches behind t to insure clearance at all points, as time is saved in the s ting of the timbers by so doing.

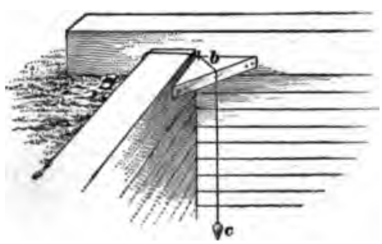


FIG. 30

In lining the shaft, the walling, or timbering, is often bu up in sections from the bottom of the excavation as the sinki progresses, the space behind being filled with sand or ot fine material that will distribute the pressure evenly over lining. In wet strata, the space behind the walling should

well rammed with clay to prevent the inflow of silt or fine sand between the timbers. Except when sinking in rock, the shaft lining must be kept within a short distance of the bottom of the excavation; this distance depends on the character of the strata, but seldom exceeds 6 or 8 feet except in unusually firm ground. The work of excavating is thus carried on in short stages, alternating with the work of extending the shaft lining.

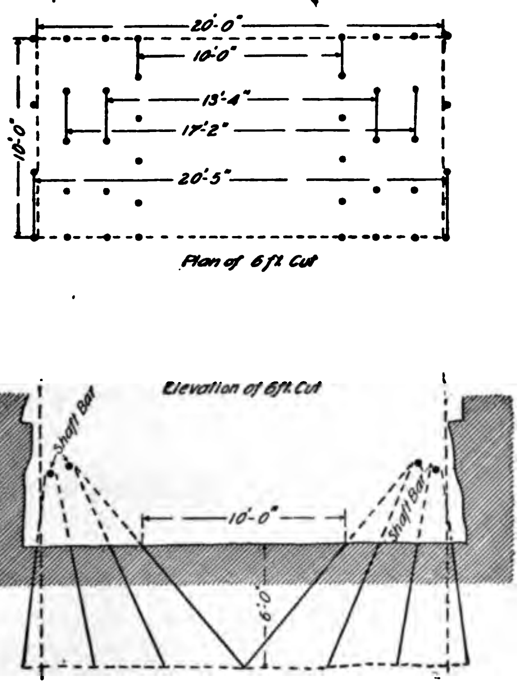


FIG. 31

53. Sinking Through Rock.—As soon as the strata become hard or firm enough to hold the explosive charge, powder is employed and churn, hand, or machine drills are used, the type of drill depending on the character of the rock. In soft rock, a churn drill is used and a light lifting shot is employed to dislodge the material from its bed. This material is afterwards broken by wedges and hammers or sledges.

For this class of work, a slow large-grained powder is required. A quick powder exploded in soft material will find vent by a single rupture of the strata without exerting the lifting force on a great mass of material, as is done when a slower powder is used. If, however, the strata are full

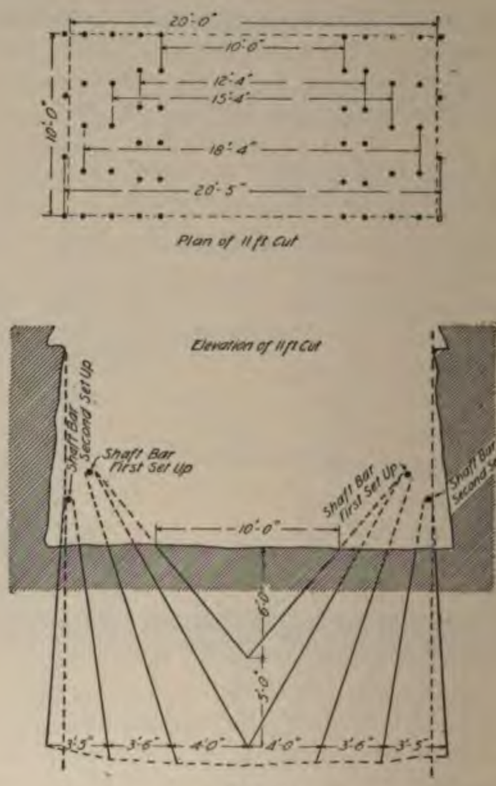


FIG. 32

of seams and cracks, a small charge of a quick powder used, since such rock will not confine the explosive force sufficiently to do effective work when a slow powder is used. In hard rock, dynamite is used, and power drills, operated by compressed air or steam and usually mounted on shaft bars, are employed.

ocation of Holes.—The general position of the their depth are about the same as described under . The first shots in a level floor should be inclined sharp angle with the floor, and are usually central ft. These holes are often called *sumping holes;* ose is to start the excavation by blowing out a ped piece of rock from the center of the floor. The enerally arranged in series, or rows, on each side of and across the width of the shaft, and are spaced distance from one The general position oles is illustrated in hich also shows the f the shaft bar on drills were mounted. sions given are those mployed in the sink-aft in a white crystal-one. In this shaft, ly 6-foot cuts were ingle series of shots the material to this e depth of cut, how-fterwards greatly in-boring the side holes shown in Fig. 32, ts averaged 11 feet, sive cuts excavating depth of 66 feet.

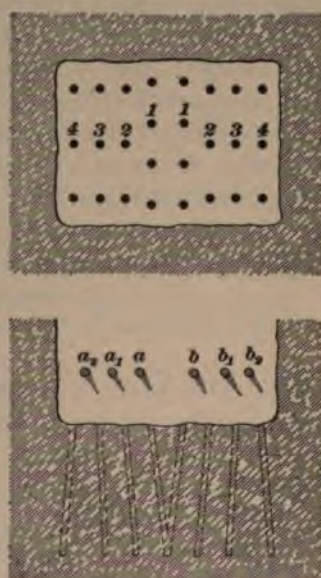


FIG. 33

nple taken from the southeastern Missouri lead strates the sinking of a $6' \times 18'$ shaft in lime-arying hardness. The position of the shaft bar the drills were mounted is shown at a, a, a_1, g. 33. The two center rows of holes *1*, or the oles, were drilled first, and each hole filled with o seven ½-pound sticks of giant powder or dyna-ining 50 per cent. of nitroglycerine. The depth of aried from 3½ to 6 feet. Beginning at the center,

the successive rows of holes, marked *1*, *2*, *3*, and *4*, respectively, on both sides of the shaft, were drilled, charged, and fired in pairs, the material being loaded and hoisted between each operation. The end holes required but four or five sticks of 40-per-cent. dynamite apiece; the entire cut of twenty-six holes used from 50 to 60 pounds of dynamite, and excavated the material to a depth averaging from 3½ to 6 feet. The average quantity of 40- and 50-per-cent. dynamite in this material was 12 pounds per foot of depth, or 3 pounds of dynamite per cubic yard of excavation. The sinking was carried on by three shifts of four men each, and the record of the sinking showed a depth of 100 feet in 30 working days, or an average of 3⅓ feet per day.

The record of the sinking of a shaft at Rossland, British Columbia, shows an average of 25 pounds of dynamite per foot of depth in a shaft 9 ft. × 20 ft., or practically 4 pounds of dynamite per cubic yard of material excavated; the rock in this case was a hard, igneous formation composed mostly of diorite. These examples illustrate the practice of sinking in rock in different localities.

55. The Long-Hole, or Continuous-Hole, Method. As in sinking in rock, much time is ordinarily lost in drilling and as machine drills cannot work close to the sides, ends or corners of the shaft, the **continuous-hole method** is sometimes used. By this method, a number of diamond-drill holes are put down at definite distances apart, and from 100 to 300 feet deep, over the area where the shaft is to be sunk. They are arranged in rows, from 3 to 4 feet apart, with the outside rows close to the sides and ends of the shaft, so that they will nearly square it up and save much digging and trimming. They are then filled with sand or water, preferably the former. The sinkers prepare for the work of blasting by removing 3 to 4 feet of sand from the holes and filling this space with explosives, which are tamped and fired.

Fig. 34 shows how the holes are arranged. The holes marked *a* are first cleaned and fired to give a loose end to the holes *b* on the outside, which are next cleaned out and

fired. This work is continued until the bottom of the hole drilled by the diamond drill is reached, when another series of long holes is drilled.

This method probably originated from one that is sometimes used in the coal fields of the Central Basin. Shafts are sunk about the diamond-drill hole that has been used in prospecting, and from which the casing has been withdrawn, or is drawn as the sinking proceeds. The sinkers charge a section of the hole, using a false bottom, and blow out a center cut.

FIG. 34

When shafts are sunk to workings already opened, a diamond-drill or churn-drill hole is sometimes put down into the open works below, and this hole kept open during sinking, thereby avoiding all hoisting of water. A long chain is used to clean out the hole when it becomes stopped up.

Both this plan and the long-hole plan are apt to cause crooked shafts on account of the divergence of the drill hole from the vertical. The advantages of the long-hole system are that sinkers need not wait while holes are being drilled; and blasting can be done as soon as debris from shots is removed. The method is said to be very much quicker than the ordinary practice of using power drills driven by air or steam, but is more expensive.

56. Timbering is usually not required for securing the sides of the excavation when sinking in hard rock. Cross-buntons to support the cage guides, pipes, wires, etc. are set in hitches in the face of the rock, and are spaced 6 or 8 feet apart. They are carefully lined and placed vertically over each other and then tightly wedged. In sinking through soft shale or loose crumbling rock, a greater amount of timber is needed for securing the sides. The sides are trimmed with the pick; and when the material is dry, a close-fitting lining of 3-inch or 4-inch planking is sufficient, the thickness

of the planking increasing with the depth of the excavation. In wet material, 4-inch timber should be used at the surface, 6-inch at 100 feet, and 8-inch at 200 feet.

57. Sinking in Swelling Ground.—Clay or marl that swells when brought in contact with air and water is difficult to excavate and support. There is no power that can prevent this swelling; it will burst any timber or break any frame that can be put in. In sinking a shaft or a slope under such conditions, the strata should be excavated for a certain depth back of the lining so as to give a good clearance between the formation and the lining all around the shaft. This space should be so arranged that a man can enter it and clear it from time to time as may be required. Drainage should be provided by cutting, in the hard pan or floor underlying such strata, a ditch connected by a pipe with the sump at the foot of the shaft. A good circulation of air should be made to travel around the space thus excavated so as to keep the clay as dry as possible.

The method of sinking through such ground does not differ materially from that used in other loose ground or rock, but the timbering of the excavation is of great importance.

SINKING THROUGH QUICKSAND OR RUNNING GROUND

58. Quicksand is sand that is so impregnated with water as to be semiliquid and therefore shifting and easily movable. Instances are on record where beds of quicksand were practically continuous for a depth of 75 feet, and as the semifluid material is often under great pressure, it sometimes bursts forth with great violence as the excavation approaches it, giving the sinkers barely time to escape. The bottom of the excavation may fairly boil, while the fluid material may rise several feet in the shaft. In different localities, as in the Wyoming Valley of the Pennsylvania anthracite region, and in central Illinois, these deposits occur in buried valleys of considerable extent, and sinking shafts in them by the ordinary methods is impossible. These conditions render sinking extremely hazardous, especially when they occur at

a depth of 50 or 100 yards below the surface. This danger makes it all the more important that the strata should be thoroughly prospected previous to sinking, and in localities where such deposits may be expected it is particularly important to have on hand an ample supply of the materials required during sinking. Timber of different sizes should be framed and ready for instant use, and pumps and piping of the proper kind and capacity should be on hand. Eight or ten pointed pipes, with perforated ends, are sometimes driven into the sand 6 or 8 feet apart and connected at their upper ends to a suitable pump. In some cases, a few hours' pumping draws off the water and the boiling sand settles and solidifies so that it may be removed with a shovel. Water can sometimes be drained from the soft ground within the area of the shaft into wells or small temporary shafts sunk adjacent to the larger shafts, thus leaving the sand within the shaft area compact and easily removable by shoveling. When the watery sand is thus drained, there is a considerable decrease in volume of the material surrounding the sides of the shaft; the shaft lining is thus frequently robbed of all supporting material for a considerable distance up the shaft and begins to separate and sag, while the shaft may be swung out of line. This decrease in volume, or displacement of the strata, due to the draining off of the water, may be carried to such an extent that the surface of the ground will sink several feet over a large area surrounding the shaft. In removing the water, a large amount of sand is also removed; the effect of its removal is often not appreciated until too late. The sand contained in the water will often cut out the pump linings in a short time, and render the pump useless; but if a layer of straw or other light material is thrown into the shaft, it will form a mesh by which the sand will be largely filtered from the water.

The methods to be adopted when sinking through such material are particularly methods of timbering, or supporting, the sides of the excavation; and the excavation must be kept timbered close to the bottom of the shaft. There are, however, certain methods of sinking that are particularly

applicable to such ground, as follows: the use of *cen piling*, *forepoling*, the use of *shoes*, the *pneumatic process*, the *freezing process*.

59. Use of Cement.—The shifting sand or loar water-bearing strata may be consolidated by injecting] dered cement into the soft ground by means of compre air, steam, or water under pressure. The cement is screened in order to free it from lumps, and the powd taken by an injector that forces it through a flexible pipe a perforated tube sunk in the soil to the required depth.

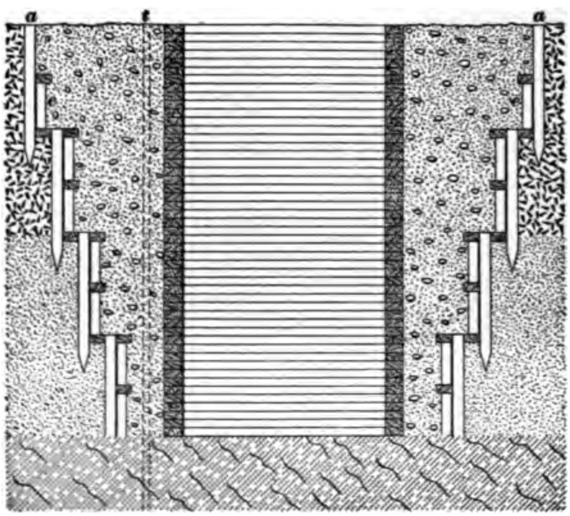


FIG. 35

60. Piling.—A bed of quicksand or other soft mat lying near the surface is often best treated by **piling.** I bed is shallow, it may be sufficient to drive a single s piles all around the site of the proposed shaft. W thicker beds of quicksand occur, it may be necessar drive several series of piles, each successive series t driven inside the former after the material has been (vated to a point near the bottom of the first piles dr The second set of piles having been driven, the mat

within these is excavated to a point near the bottom of the piles, and, if necessary, a third set of piles is driven within the second. This method is illustrated in Fig. 35.

After driving, the first set of piles *a* should be strengthened by timber frames or timber sets at their top and halfway of their length, as the material is excavated from the space they enclose. It is important that these frames should be set promptly and braced by cross-buntons; they are supported by punch blocks *e*. As will appear from the figure, it will be necessary to set the first sets of piles back a sufficient distance from the shaft to allow for the decreased size of the excavation when each series of piles is driven. This distance is easily calculated when the depth of the sand beds is known (and this is given by the bore or drill hole *t* made beforehand).

In some cases, the soil at the surface may be firm for a considerable depth, but underlaid by a flowing bed of quicksand. In this case, the excavation of the overlying soil may be done in the usual manner, and after this is lined or curbed the piles may be driven from the foot of the excavation in the same manner as from the surface. In this system of sinking through watery strata, the permanent shaft lining is built up as soon as the rock is reached. The space between the shaft lining and the piles is then filled with clay, where this can be obtained, or the timbers are backed with a sufficient thickness of cement, and this, in turn, with the material excavated.

61. Forepoling.—Fig. 36 shows a method of **forepoling** for sinking through quicksand, very similar to the method of forepoling described under Tunneling. Strong timber sets *j* are framed to the sides of the shaft. As each set is put in, it is suspended from the timbers *a* above by the light strips, or lath, *f*, while the punch blocks *b* are set between the frames to hold them apart. Two-inch planks with the ends sharpened are used for the spiles *k*, and are driven downwards in an inclined position behind the lower timber set. Before driving the spiles, the tail-pieces *C* are spiked to the

lining just above the lower timber frame; the spiles are then driven as the excavation advances until their tops reach this tail-piece. Another set of timbers is then placed in position at the floor and tied to the timbers above, and the same operation repeated, driving the spiles and excavating the material as rapidly as possible. This process of forepoling may be carried on at any depth below the surface where the strength of the timbers will resist the pressure of the sand.

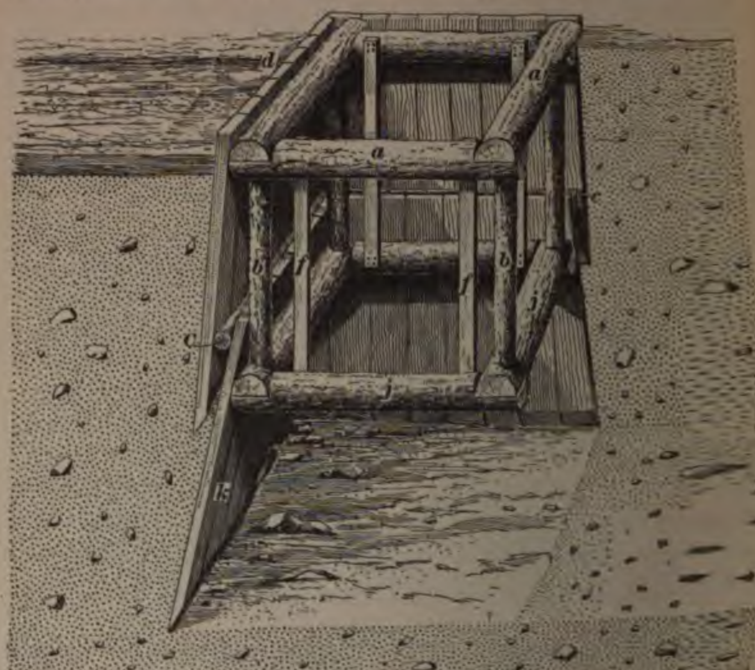


FIG. 36

Another method of forepoling, adapted to a greater depth below the surface and a greater thickness of sand, is illustrated in Fig. 37. This method is similar to that last described, except that the spiles are driven in at a flatter angle. The timber frames, however, are placed somewhat closer and no tail-piece is employed, the tops of the spiles bearing against the timber above instead of against the tail-piece.

. 38 illustrates the use of breast boards where the a tendency to rise shaft, and must be keep it down. The emoved a little at a mp is carried ahead llar excavation, as driving short piles in a small frame. slow and tedious, s great care and

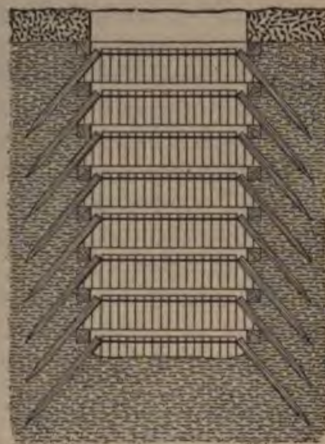


FIG. 37

ther method of fore- nished by the inter- nnel bars, Fig. 39. cess, the shaft is et larger each way than the size desired, and

FIG. 38

ordinary manner to the sand; thus, an $8' \times 16'$ e started as 10 ft. $\times$ 18 ft. The channels or angle

irons are shown in Fig. 39. The lining forming the sides is composed of alternate channels *a* and *b*. The channels *a* have **Z** bars *c* riveted to them, which engage and interlock the edges of the channels. The channels *b* have angle irons *d* riveted to them, thus forming grooves in which the sides of the channels *a* run. The corners of the shaft lining are made of three angles *e* riveted together, as shown, which interlock with the side and end channels *a* by means of the **Z** bar riveted to *a*. Heavier sections can be used, which would make the thickness of the metal about ½ inch. When sand is reached, these channels are set plumb in a solid frame inside of the

FIG. 39

shaft lining, and are driven vertically downwards through the sand to the solid material, if possible, before any sand is excavated. No one channel should be driven more than 2 feet ahead of the rest. A perfect fitting anvil, or clinker, is used to protect the head of the channel bar while driving. Channels 12 feet long are readily driven their entire length into the sand. The sheathing can be driven to varying depths by feeding in pieces from the top, thus driving the preceding one down, in the same manner that a follower is used in driving piling. The individual members, engaging and interlocking, slide on each other so that one can be driven at a time, and thus afford an opportunity to drive channels all around a boulder,

should one be encountered. The channels interlock nearly water-tight, and, by cementing above and below them, the water may practically be shut off. The channels take up about 5 inches, while 6 inches should be allowed for timber. The price of this sheathing or lining is about $2.50 per square foot, or $120 per lineal foot for an 8′ × 16′ shaft. The channels are either left as a permanent lining or they may be drawn after a timber lining has been laid. They are cheaper than steel shoes or drums.

64. Shoes for Shaft Sinking.—The shoe is a simple contrivance that, in different forms, has been well known to engineers and contractors for many years in connection with the work of excavating. It consists of a frame of the same shape as the shaft being sunk, and may be either metal or wood. Attached to its bottom is the cutter, which is of steel and beveled so that it will sink easily into loose ground. The shoe is usually open top and bottom, but sometimes so arranged that the top can be closed tightly with steel plates, to resist the sand pressure from the shaft bottom. The upper part of the shoe is outside the shaft lining from 12 to 16 inches, and the lower part is usually divided into compartments by braces that brace the sides and ends.

In principle, the plan of sinking by a shoe is similar to the method of tunneling in soft ground with the use of an advance shield, except that shaft shoes, in America, are usually rectangular in shape, while the shield in tunnel driving is cylindrical. As the material is excavated from beneath the shoe, the shoe drops by its own weight or on account of pressure applied to its upper surface by weights laid on it or by means of jacks, generally the latter, thus walling back the sand, while the lining is being put in place. Only enough material is excavated from underneath the shoe and it is moved just far enough ahead to permit the placing of one set of timbers at a time; if planks are used for the shaft lining, they are put in flatwise. The shoe should descend uniformly at all points, and should be carefully leveled before the timber is placed.

65. Fig. 40 shows the plan and elevation of a steel shoe that is quite commonly used. It is made of ¼-inch steel boiler plate braced as shown, has a height of 30 inches under the shaft timbers, and a sheet-iron lap 18 inches deep extending outside of the timbers. Fig. 41 shows it in position at the bottom of the shaft, as well as the manner of supporting it and controlling its descent. Four hooks, or claws, are provided, which may be screwed into the lower

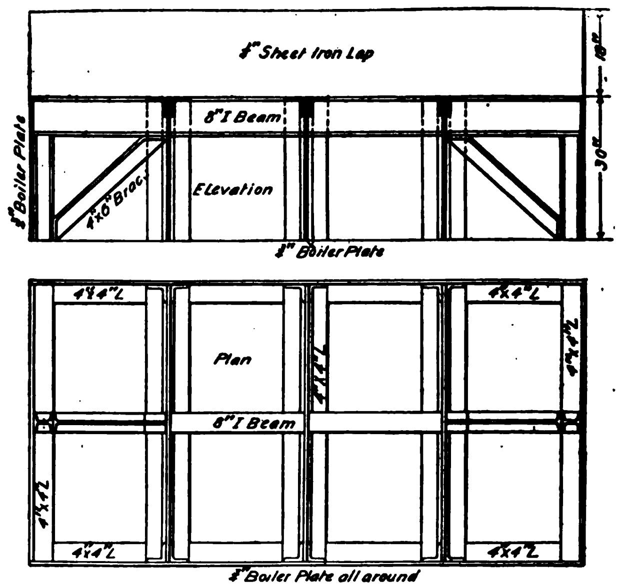


FIG. 40

couplings, Fig. 42. To each of these hooks is fastened a strong chain attached to the frame of the shoe; by this means, the downward progress of the shoe is controlled, and there is less liability of its becoming wedged.

One of the disadvantages of using the shoe is the fact that it is apt to be stopped by boulders, clay seams, or other obstructions, one part remaining stationary while the other goes down, thus throwing the shoe out of level and wedging it so tightly that it cannot be moved, and causing the shaft to be thrown out of line and perhaps abandoned. By means

of the chains shown in Fig. 41, this difficulty is partly overcome, as by their use the shoe can be held stationary until the obstruction is removed. The chain may also be slacked at any time to allow the shoe to move.

The cross-beams of the shoe frame furnish also a good support for the planks that are used in the shaft lining. As the shoe is lowered 2 inches, or the thickness of a plank, the

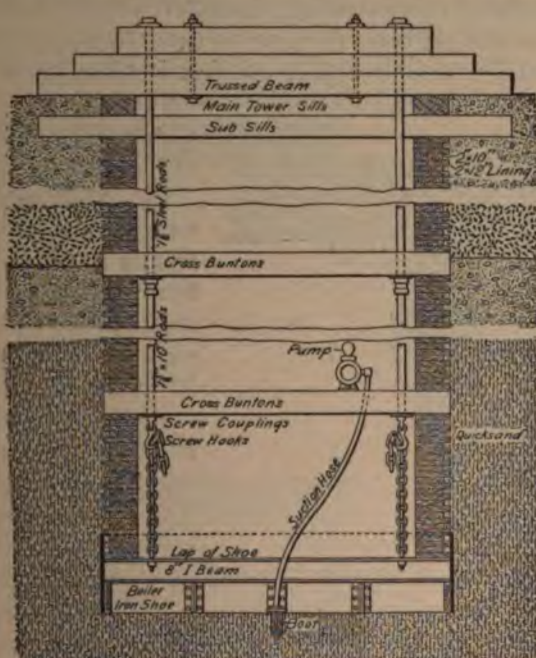


FIG. 41

latter is slipped in place and spiked upwards from beneath, 40-penny nails being used for this purpose. The jacks for forcing down the shoe are shown in position in Fig. 43.

The shoe is sometimes forced downwards by the weight of the lining, if this rests directly on top of the shoe instead of hanging from the top of the shaft. The lining is then built from the surface by adding set on set, the increasing weight gradually forcing the shoe through the soft material.

A good frame is at least 3 or 4 feet high, and should extend from the shaft to solid ground so as not to be affected by any movement at the surface due to shifting sands, as before described. It should be strong enough and supported in such a manner that it can carry the weight of tower and sheaves, as well as the lining, if necessary, although the tower should not be placed on the frame if it can be avoided.

Fig. 41 shows a simple frame built directly on top of the sills of the shaft. Fig. 43 is a more elaborate frame built up as follows: A 30″ × 40″ platform of 2-inch plank *a* is first laid on the surface about the shaft. On top of this and running parallel to the long side of the shaft are steel rails *b* (about 60 pounds), which form the foundation of the solid timber trusses. Each truss shown is made of eight pieces of 12″ × 12″ timber, the bottom piece *c* being 48 feet long and the next *d* 4 feet shorter, and so on to the top one *e*, which is 20 feet in length. Across these trusses are placed two 16″ × 16″ timbers *f* 20 feet long; nearly over the side walls of the shaft and through these timbers pass the rods from which the lining is hung. In this case, the rods g, g' are connected by the coupling *h* shown in detail in Fig. 44. The rod holds the lining by means of the casting *a*, which is fastened to the shaft lining with lagscrews. The shoe is hung from the rods by the chains *k* and the swivels *l*, Fig. 43.

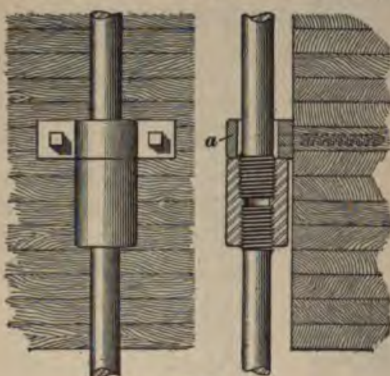


FIG. 44

67. The **Triger, or pneumatic, method,** which is occasionally used both for shafts and tunnels, is an adaptation of the caisson method used in bridge work. It has very rarely been used for sinking mine shafts and it is necessary, therefore, only to give the principle on which it is operated.

s commonly known as the Triger method on account of successful application in France by M. Triger a number ears ago. In this method, a cylinder of cast iron, made successively adding one ring to another at the surface, is e to gradually sink into the loose ground, either by its own ght, by weights piled on top of the cylinder, or by means ressure applied through jacks. In order to keep out the r from surrounding strata, compressed air is led into a ed chamber at the bottom of the iron cylinder, the pres- of the air being kept just sufficient to prevent an inflow vater and loose sand. This chamber forms the working e in which the material is excavated; above it, and con- ed to it by suitable trap doors, is another closed space, vn as an *air lock*. This air lock, by means of trap doors e and below, gives a means of communication between working chamber and the surface. A person enters it ugh the upper trap door; after closing this door he allows compressed air from the working chamber to enter, by ns of suitable valves, until the air has reached the same sure as that in the working chamber or caisson; the r trap door, which leads to the caisson, is then opened he descends into the working chamber. In order to the caisson, the opposite procedure is adopted.

ie excavated material can either be removed through the ck, or it can be blown out through a pipe by means of ressure after being mixed with water. If only a few lers are found during the sinking, they are carried down e caisson and are hoisted out after solid material has reached and the roof of the caisson cut way. If many lers are encountered, they must be blasted and the pieces ed out through the air lock. In some cases, the metal g on top of the caisson forms a sufficient lining for the ; in other cases, it is necessary to build a lining of tim- r metal inside of this casing.

3. In the **Pœtsch** and the **Gobert freezing proc-s**, a sufficient thickness of the fluid material of a sand is frozen to form a substantial wall about the proposed

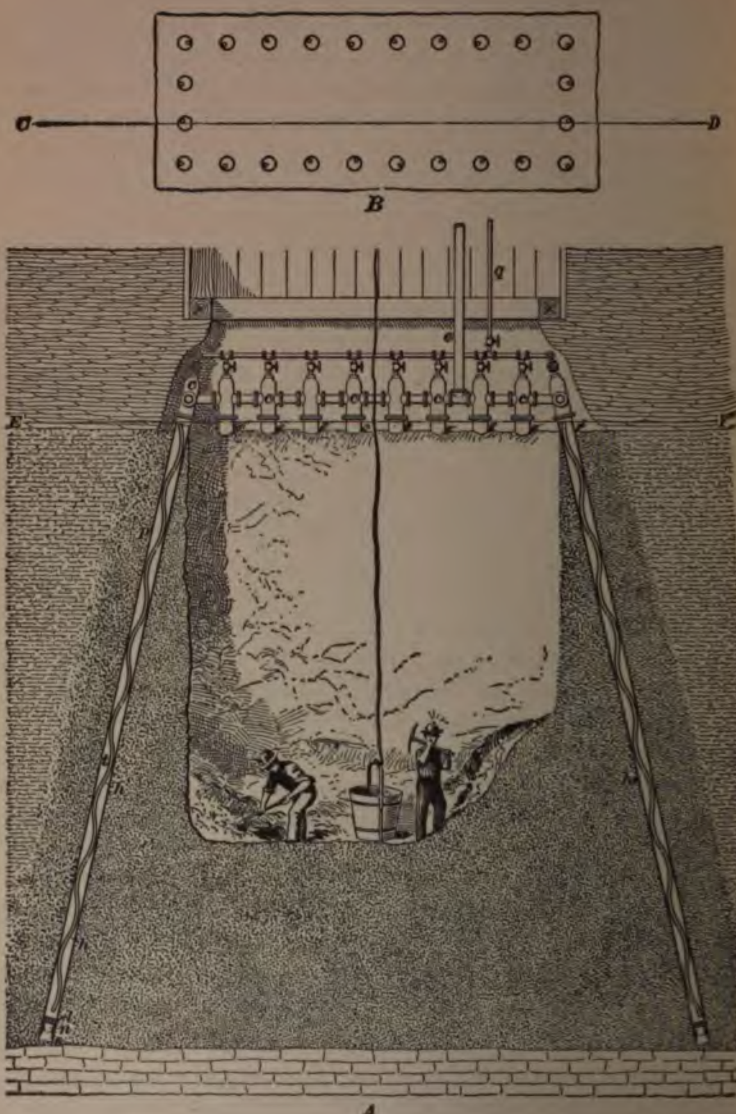


FIG. 45

shaft so as to permit the excavation of the material enclosed within this area. Surrounding the shaft, a series of holes, Fig. 45, from 6 to 10 inches in diameter, is bored through the sand bed and cased with ordinary well casing; or if the sand is very fluid the casing may be driven through the sand. These holes if bored from the surface are usually vertical, but if bored from a point in the shaft a few feet above the bed of sand, they are inclined as illustrated in Fig. 45. They are not more than 3 or 4 feet apart, in order to insure the thorough freezing of the sand between them. Inside these casing tubes, smaller ones, usually about 4 inches in diameter and closed at the bottom, are let down to the solid stratum, and the outer temporary casings withdrawn. The 4-inch tubes are closed at the top with metal cap pieces, and each contains a 1-inch tube that extends almost to the bottom. The 1-inch and the 4-inch tubes are connected at the surface to circular mains, each vertical tube being fitted with a screw-down stop-valve so that it can be cut off from the main.

The two freezing processes are distinguished by the character of the freezing medium. The Pœtsch system uses a brine comprised of a solution of calcium chloride (or magnesium chloride) passed through a cooling machine on the surface, where its temperature is reduced to about 8° F. below zero. The solution of chloride of calcium is pumped through the smaller tube to the bottom of the hole, and then rises through the larger tube to the surface. In this process, the material is frozen first and hardest at the bottom where the greatest pressure is. Since this freezing mixture is much heavier than water, the pressure inside the pipes is greater than that outside, so that there is a tendency to burst the tube conveying the freezing solution, thus allowing it to escape into the sand outside and rendering it incapable of being frozen.

In the Gobert system, anhydrous ammonia is sent down the inner tube (which is then usually made of copper) and allowed to vaporize in the tubes, thus freezing the ground directly instead of allowing it to cool a mixture that

reezes the ground indirectly, as in the Poetsch process. The ammonia gas is drawn off by a pump and reliquefied by compression and used over again. As the pressure is less inside than outside the tubes, if a leak occurs in the tube any water entering will be immediately frozen and the leak thus stopped.

The pipes may be driven well outside of the intended shaft area and a wall of earth frozen around the shaft, the central portion or shaft area being removed before it is frozen. In most cases, however, the ground has to be frozen solid and then blasted as though it were rock.

KIND-CHAUDRON SYSTEM

69. The **Kind-Chaudron system** is applicable only to circular shafts, and is adapted to sinking through strata with heavy feeders of water that render the work of sinking by ordinary methods wholly impracticable. The excavation is carried down to water level by the ordinary methods of sinking, and the shaft is lined to this point with timber or masonry. Boring is then commenced by means of a large trepan suspended in the shaft. The diameter of the excavation to water level must be sufficient to allow for the thickness of the walling or timbering, so that the latter will not interfere with the use of the trepan for sinking below this level. The excavation is effected in two or more successive operations. The first trepan used cuts a hole in the center of the shaft from 4 to 5 feet in diameter; this is called the *guide pit* and is kept at least 35 feet in advance of the second cut, which is made by enlarging the guide pit by means of a special trepan. During the entire boring, the water is allowed to accumulate in the hole, which often stands full, and the boring is done underneath the water.

The first *trepan*, or cutting tool, Fig. 46, consists of a horizontal bar *T* of wrought iron having steel teeth *B* attached below. The action of the cutting tool is the same as that of a churn drill. The trepan is suspended in the shaft by means of heavy iron rods attached to a large walking beam

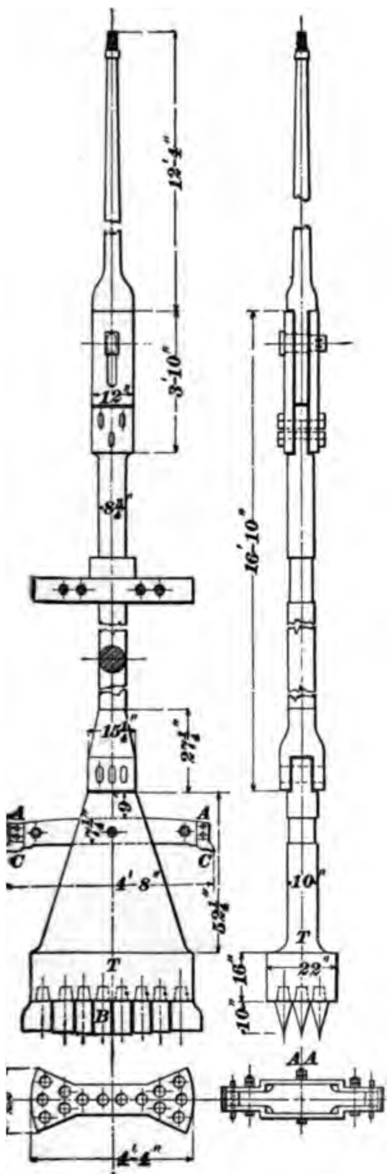


FIG. 46

at the surface, and the weight is partly balanced by a counterpoise at the other end of the beam. An engine operates the beam, raising the rod a height varying from 10 to 20 inches and dropping it to the bottom. To avoid the shock caused by a cutting tool of such great weight, a slide bar similar to the jars in the American rope method of drilling, described in *Rock Boring*, is used. The trepan is turned by men who stand on a platform built above the level of the water in the shaft. In making this first cut, the hole is cleared by means of a sheet-iron sand pump about 6 feet long, which is raised and lowered by the trepan rods.

The second cut is an enlargement of the first and is made with a trepan that usually weighs from 36,000 to 50,000 pounds. It is quite similar to the first trepan, being formed of a wrought-iron bar having teeth attached to that portion of its length that exceeds the diameter of the guide pit. It is guided by means of a cradle, or iron

bar, that fits closely within the excavation made by the smaller trepan. The teeth on the large trepan are so set that they cut the bottom of the annular portion surrounding the guide-bore pit into a sloping surface, so as to allow the fragments and cuttings to roll into the smaller shaft, where they are caught in a sheet-iron bucket previously lowered to the bottom of the guide-bore pit. Sometimes scrapers, which drag around after the trepan and sweep the material down the incline and into the bucket, are provided. The excavation having been made of the required size in two or more successive operations, the shaft is lined with iron tubbing, which is built in sections $4\frac{1}{2}$ or 5 feet high and added at the top as the whole is lowered from the surface.

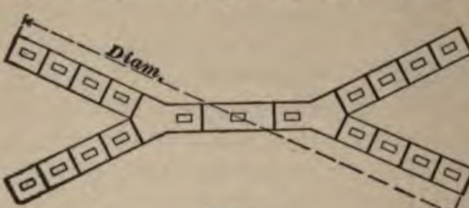


FIG. 47

To assist in lowering the great weight of the steel tubbing, it is provided with a water-tight bottom in which is a nozzle having a stop-cock by which a sufficient amount of water can be let into the tubbing to sink it gradually. The tubbing is thus floated in the shaft till it finally rests on the solid bed leveled to receive it. A special moss packing below the tubbing makes a water-tight joint when the water is pumped out.

70. The **Lippman system** differs from the Kind-Chaudron in that the shaft is bored the desired diameter at one operation by using the cutting tool shown in Fig. 47. The tools are made and the cutting teeth are secured in a manner similar to that employed in the Kind-Chaudron method.

SHAFT TIMBERING

71. General Principle.—Inasmuch as shafts are very generally lined with timber in America, the terms *shaft timbering* and *shaft lining* are often used synonymously; although the term shaft timbering will be here used

generally, it must be understood that many of the principles given apply equally to masonry, steel, or any other form of shaft lining. Yellow pine was formerly thought to be the only wood suitable for shaft lining, but on account of its great cost it has been largely superseded by hemlock, black and white oak, and other woods. An ideal plan would be to have the timber cut of proper length and notched or framed before being delivered, but this is not often practicable, and in general the timber is framed on the ground by contract at so much per set (a set being one horizontal layer of timber of whatever size is used). If the framing is done by day labor, two men are kept busy cutting and carrying timber about one-third of the time, and are employed on drills or at other labor when not framing.

The object and character of **shaft timbering** vary with the nature of the enclosing strata and with the depth below the surface. Thus the methods used in rock, in loose material, and in watery or running strata are very different. In a shallow shaft, however, it is not advisable to change the lining to suit changes in the strata, and the thickness is made throughout so as to meet the requirements at any point of the entire depth.

In hard material, only such timbers are introduced as are necessary to furnish support to the guides, pipes, wires, etc. that are carried down the shaft. In loose material, the object of timbering is to give support also to the sides of the excavation. In watery strata, the pressure of the water behind the timber is another point that must be considered. Water encountered in the sinking of a shaft finds its way at once to the excavation or follows down behind the lining and collects in the bottom of the shaft, unless kept out by the shaft lining. If the lining is built tightly against the sides of the excavation, so as to impede or stop the flow altogether, the water rises behind the lining to the water level of the strata, and the lining is subjected to a pressure dependent on the head of water. The strength of the lining must be sufficient to withstand this pressure. In such cases, the following formula may be employed to

determine the thickness of white-pine lining that will resist a given head of water:

$$t = .016\, s \sqrt{d}$$

in which t = thickness of white-pine lining, in inches;
s = clear unsupported span of timber, in inches;
d = depth, or head, of water, in feet.

NOTE.—While in the statement of this formula white-pine timber is used, the same formula will give results that are practically correct for the other timber used in shaft linings.

It must be remembered that the head of water supported by the curbing does not mean the depth of the curbing below the surface, as the water rarely, if ever, heads to the surface.

EXAMPLE.—Find the thickness of white-pine curbing required for a coffer dam when the depth of the water head is 100 feet, the clear span of the end plates of the shaft being 7 feet.

SOLUTION.—Substituting the given values in the formula, we have $t = .016\,(7 \times 12)\sqrt{100} = 13.44$; hence a 14 in. timber would be used. Ans.

72. Timbering in Rock.—Where a shaft or a portion of a shaft is excavated from hard-rock strata, the only timbering necessary is the cross-timbers, or buntons, to support the guides in the hoisting compartments of the shaft and the lines of pipes, or wires. The buntons b, Fig. 48, are set in hitches h, cut in the rock face and firmly wedged in line, one above the other, by wedges w, w. At times the hitches are cut square and those on one side made deeper to permit the other end of the stick to be placed in the hole opposite.

FIG. 48

The buntons are spaced from 6 to 8 feet apart, one above another, on each end of the shaft, and between the several compartments of the shaft. When it is desired to separate the compartments of the shaft, as in the case of an airway or manway, planks are spiked to the buntons or built between them to form the partition.

73. Timbering in Loose Dry Material.—In good ground, shafts have been sunk to a depth of 200 to 300 feet by using $3'' \times 12''$ planking set on edge, but beyond this depth it is better to use 4-inch or 5-inch planks. When an especially soft, wet, or crumbling stratum is met, such as wet sand or fireclay, the planking is sometimes laid flatwise. If the sides of the shaft are not self-supporting and tend to

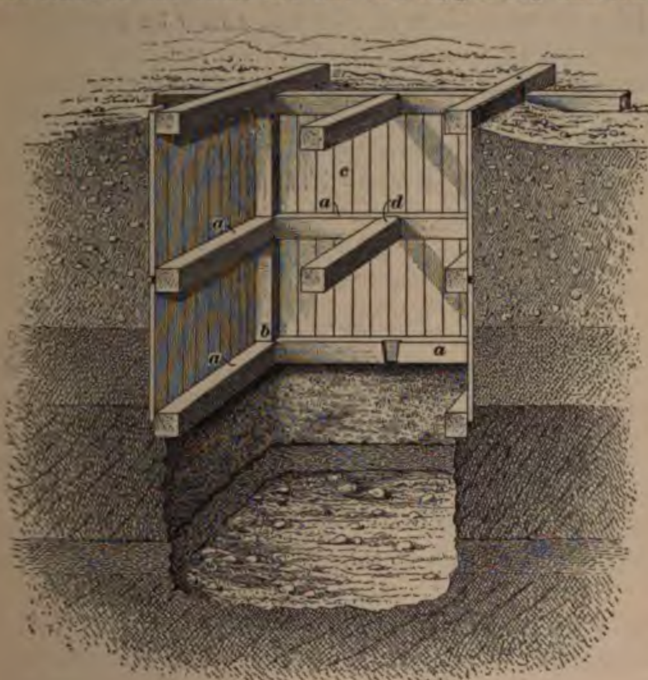


FIG. 49

crumble into fragments of varying size, if boulders that are likely to become detached are found, or if the strata are jointed and faulted, then, in order to preserve the shaft and to avoid accident from earth or rock falling to the bottom from the side walls, it is necessary not only to line the entire excavation with plank, but this planking must be supported by heavy timber sets placed inside the planking as shown in Fig. 49.

These timber sets *a*, *a* are placed at regular distances apart and are separated by the posts *b*. The lagging *c*, composed of closely fitting planks, may be driven in behind the timber sets, or it may be first placed in position and the timber sets or frames added afterwards. Cross-buntons *d* are also inserted in each set to separate the compartments. Where a greater strength of timbering is required than is given by the form shown in Fig. 49, the sets *a* may be placed one on top of the other, i. e., *skin to skin.*

An open crib of timbers, similar to that shown in Fig. 50, may also be employed in loose ground, the openings between the timbers being gradually filled up compactly by the loose material. After the timbers have been placed in position, triangular strips, or corner pieces, *A* are spiked to them in each corner of the shaft. This open crib may be built either from the top downwards or from the bottom upwards.

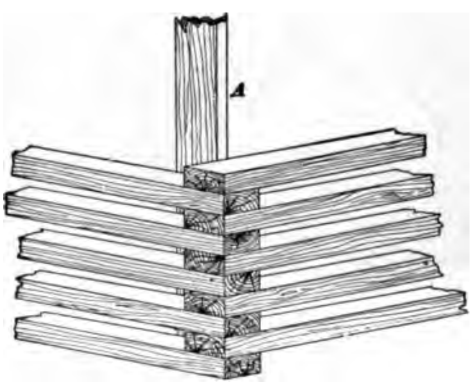


FIG. 50

74. Instead of building the timbering from the top downwards, it is frequently built upwards from the bottom in sections of 10 to 15 feet, depending on the character of the ground. The bottom of the shaft is carefully leveled with a carpenter's level and straightedge; and, by measurements made from the plumb-lines hung from the shaft corners, a set of timbers is placed so that the inside is in line with the edge of the sills, or shaft templet. After the whole set is accurately leveled and joined, wooden wedges are driven between the timbers and earth at each corner. The wedges should be long and tapering, and while one man drives the wedge the other holds the set in place with a bar. Great care is taken to get this first set level and in line with the

shaft templet, as it is the foundation for the other sets. After this foundation set has been placed in position and wedged, another set is placed on it and leveled and wedged in like manner. In this manner, the work is continued until he templet or next section of timbering is reached. If the inker has measured correctly and has made due allowance or the number of sets required to close the distance between he shaft bottom and templet, his sets will close this space xactly. The inside edges of the planking are brought flush ith the inside edges of the templet, and iron straps, about in. × ¼ in. × 15 ft., provided with nail holes are hung om the surface downwards, connecting all the planking and nging it from the templet. The straps or hangers are aced on the sides and ends of the shaft at distances of to 3 feet apart, and they break joints vertically as the nbering proceeds. If a small space is left between the st set and the templet and the planking does not close actly, a *closing set* is necessary. For this purpose, a gular set is cut down to the required size by the rip saw adz. However, the sinker should make his measurements d calculations so that no closing sets are required.

No cavities should be allowed to remain behind the timberg after it is completed, except in round that swells. If cavities are und in the strata, or if more earth as been taken out than was necesary, the space must be filled with shes, straw, etc.

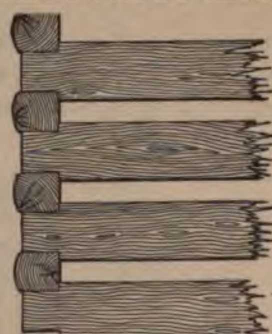


FIG. 51

75. Timbering in Swelling round.—A form of timbering ten employed in swelling ground a cribwork of heavy timbers, such is shown in Fig. 51. These timrs are notched together after the fashion of a log cabin. ne side of the timbers may be faced, as shown in the figure, as to form the face of the shaft, but the back of the timrs is preferably left round. When the ground swells, the

material more readily works out between the timbers, and can be removed from time to time, as it may be found necessary. An important feature of the work in dealing with swelling ground is to keep the material as dry as possible, since the moisture causes the swelling. In such swelling ground, a space at least 6 inches wide is sometimes cut out all around the sides and ends of the shaft, and filled in loosely with moss, straw, sand, or ashes, allowance being made for the probable expansion of the ground. When the timbering, by bulging, shows signs of excessive pressure behind, as shown in Fig. 52 (*a*), the difficulty may be overcome by carefully removing two or more planks from the shaft at this point, and excavating such material as may be necessary, all around behind the timbers, as shown in (*b*). The manway thus

FIG. 52

formed should be carefully drained by a pipe conducting the water to the sump or other lodgment. This manway should be timbered and cleaned out from time to time, as may be necessary; the bulged timbers of the shaft should also be replaced by good ones.

76. Timbering in Very Wet Ground or Quicksand. In wet ground, timbers should be closely joined. At times, it is desired to make a water-tight joint between each set of timbers to keep the water from entering the shaft; for this purpose, timbers have been laid in cement, but better results are obtained by backing the timbers with cement. A form of timbering that always gives good results, introduced for the first time in the sinking of the Ladd shaft at Ladd, Illinois, is that shown in Fig. 53, which illustrates a section of curbing passing through a stratum of quicksand, and through

soft material overlying the same. At a point above the soft material, the $3'' \times 8''$ curbing plank employed for the shaft lining is laid flatwise, as shown at *a*, increasing the thickness of the curbing from 3 to 8 inches. When the quicksand is reached, the 8-inch plank is alternated by 6-inch plank, forming the corrugated backing shown at *b*; the effect of this rough backing is to clog the drainage that would otherwise find its way down the back of the curbing, and greatly reduces the amount of water entering the shaft.

FIG. 53

77. Setting Timber in Quicksand.—The chief difficulty in sinking through quicksand is that arising from the flow of the soft material into the excavation before the timbers can be placed in position. To prevent this as far as possible, the excavation should be timbered well down to the bottom of the shaft. Fig. 54 shows more or less accurately the inflow of sand and the method of setting the timbers. The lower timbers have been set, jacked up, and spiked. Blocks *a* are used to support the back of the lining. These blocks are knocked out by the next

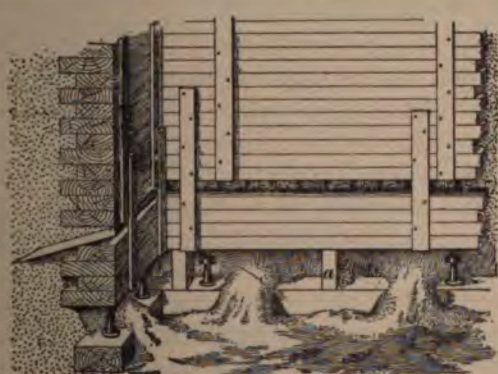


FIG. 54

set of timbers when it is driven to its place. It is necessary to provide a temporary foundation for the jacks, which in this case is afforded by the sills shown. The form of lining employed

is the alternate narrow and wide plank laid flatwise. To reduce the flow of sand temporarily, spiling has been driven between the timbers; but the spiles must be removed before they throw too much weight on the lining. To support the timber while the jacks under the set are being lowered far enough for a new timber to be placed over them, cleats are spiked on the timbers as fast as each timber set is laid in place. If the timbers cannot be forced into place by hand or driven with a sledge, a jack, similar to those shown in Fig. 54, is used, being fastened to a piece of $6'' \times 6''$ or $8'' \times 8''$ timber, about 1 foot shorter than the inside dimensions of the shaft.

78. Timbering a Wet Surface and Subsoil.—It frequently happens that much annoyance is caused in an otherwise good shaft by a large amount of surface water finding

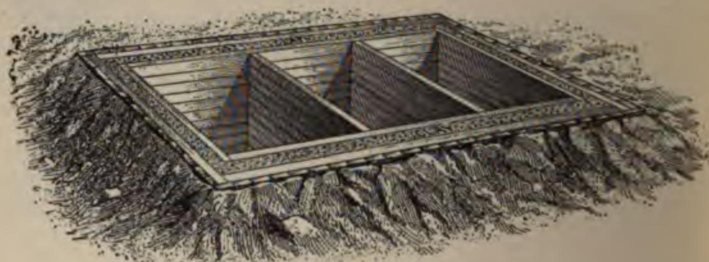


FIG. 55

its way into the shaft through the drift and subsoil overlying the hard pan. When this is the case, it will pay to enlarge the shaft through the drift and subsoil to the hard pan, and line the excavation in the ordinary manner by light timber frames and sheathing plank behind them. The excavation should be carried about 2 feet into the hard pan, in order to afford an opportunity of making a good water-tight joint, so as to exclude the surface water from finding its way into the shaft. The heavier permanent shaft lining is then built up from the bottom within this enclosure, the space between the two linings being filled with clay well rammed as the timbers are placed in position. This forms a water-tight shaft lining, as shown in Fig. 55. The thickness of the clay should not be less than 10 or 12 inches.

Water Rings.—Most shafts make more or less)th during the sinking and after they are completed, ›rtain amount of water will usually be found flowing : rock or the lining. To draw this water away and t the annoyance :s constantly run- ›wn the shaft, a ay be cut in the out the shaft as n Fig. 56, or, if ıft is timbered, **rings,** or **curb** are built in the as shown in

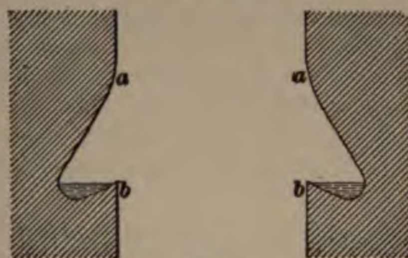


FIG. 56

These catch the water as it runs down the rock or ıd conduct it usually to one corner of the shaft, from a pipe leads to the sump at the bottom or to a lodgment or coffer dam.

FIG. 57

80. A **coffer dam,** as shown at *k*, Fig. 60, is a section of solid lining designed to dam back the water coming from a stratum of water-bearing rock encountered in the sinking of a shaft. At any point where a water-bearing stratum of rock is encountered, sufficient material is excavated from the watery strata to allow a good cement backing to be inserted behind the shaft timbers; this excavation should be carried a short distance into the underlying and overlying strata so as to form a ;ht joint with each stratum. The space thus exca- filled with concrete either at the same time that the are put in place or later from an opening left in The timbering is also often made much stronger

and heavier at this point. The operation of damming back the water is known as *coffering*.

81. Lodgments, or **basins**, are openings from 6 to 8 feet high, equal in width to the shaft, and driven, usually, from the end of the shaft. They are intended as receptacles for large quantities of water made in sinking and extend from 50 to 60 feet back from the shaft. They are, as a rule, constructed on rock or other hard ledges through which the shaft passes. The hard stratum is smoothed and a floor made of heavy timber or brick laid in cement; the sides are treated in the same way, and the chamber thus made is arched over; across the mouth some 8 or 10 feet from the shaft lining, a dam of timber or brick laid in cement is built, as shown at Fig. 58 (*a*). Instead of damming the water as shown at (*a*), it may be caught in a basin as shown at (*b*). An opening large enough to admit a man's body is left in the dam so that the lodgment can be periodically examined. In the same space between the dam, or basin, and the shaft, a pump is erected and the water pumped to the surface, the power for the pump being supplied from the surface. As much of the water in a shaft usually comes from within a comparatively short distance of the surface, the use of such lodgments saves pumping from the shaft bottom.

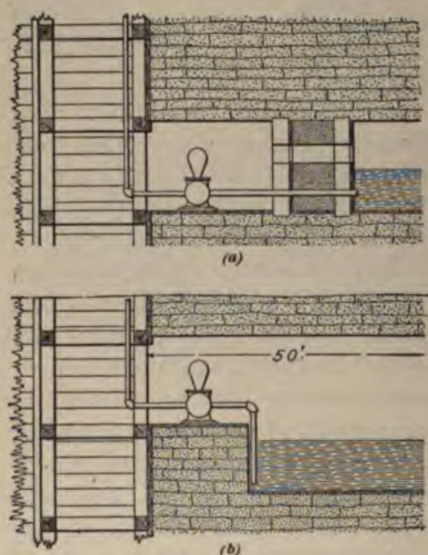


FIG. 58

82. Sump.—The shaft excavation is always carried far enough below the cage landing at the shaft bottom to provide

catch basin, or **sump,** large enough to hold the water raining into it from the shaft and from the workings during l hours. The depth of the sump will be limited by the iction of the pump or the depth from which the pump will aw water. If the area of the shaft is not sufficient to afford e required capacity, the sump must either be extended at e end or a second sump provided.

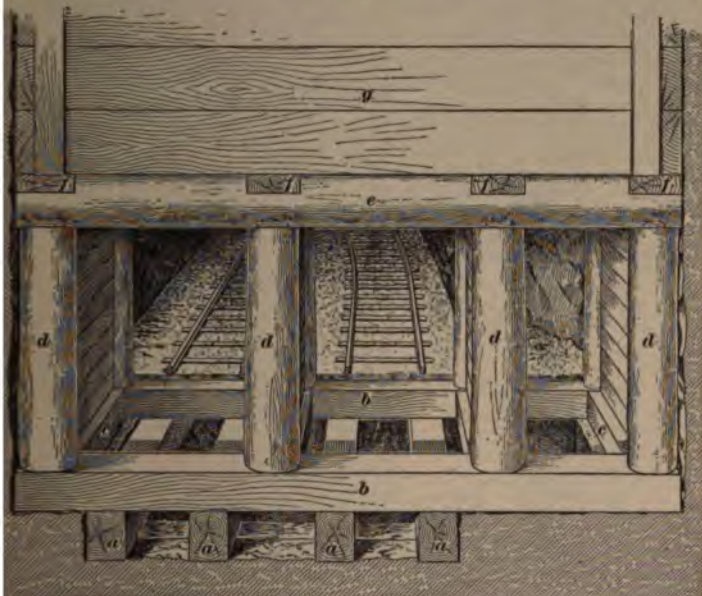


FIG. 59

83. **Square Frame at Foot of Shaft.**—When the ttom of the shaft is reached and the sump has been made carrying the excavation several feet below the floor of e seam, a heavy substantial frame must be built for the pport of the shaft timbers. The cage landing is first made placing two heavy square timbers *a*, Fig. 59, under each istway. These timbers should be 10 in. × 12 in. or 12 in. 16 in., according to the size and weight of the cage, and ould occupy a position about under the rails on the cage. iey are well bedded in the strata on each side of the shaft,

and set low enough to make the floor of the cage, when the latter is resting on the timbers, level with the floor of the

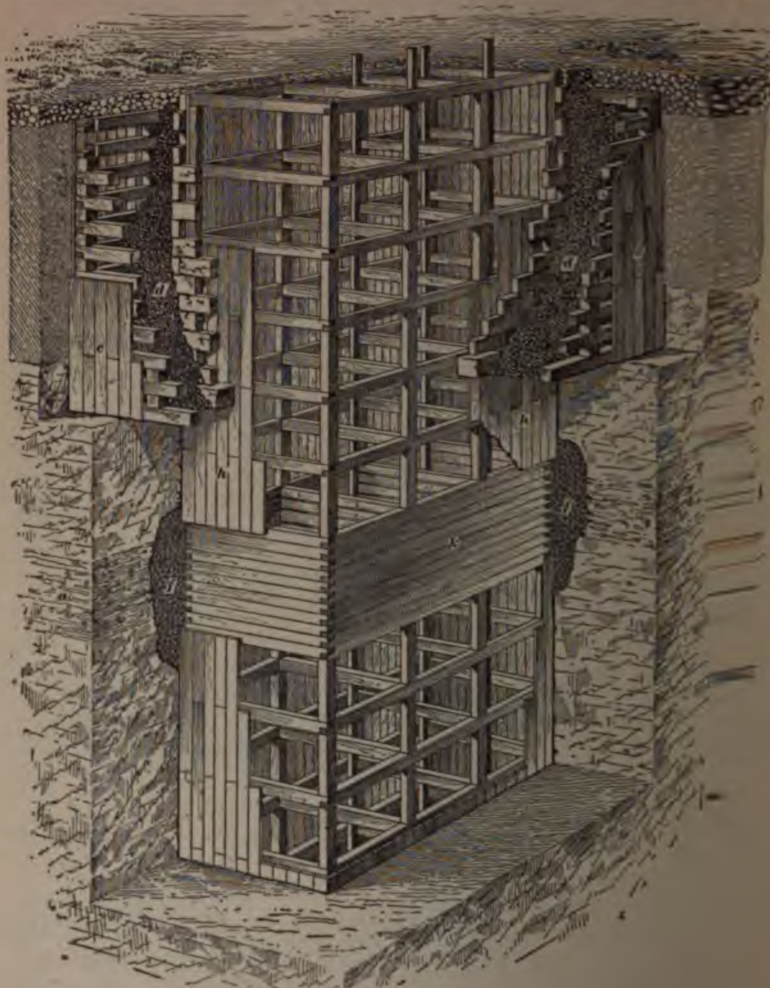


FIG. 60

landing. When this has been done in each hoistway, heavy longitudinal sills *b* are laid over them, one on each side of the shaft; cross-timbers *c* are boxed into the sills to keep them

right distance apart and to form a solid frame for the ge landing. Substantial posts *d* are then set at the corner each compartment. Heavy caps, or collars, *e* are framed to t on these posts, and cross-timbers *f* are boxed into these s above. The whole frame is brought to such a height will correspond to the height of the heading, and the shaft bers, or lining, *g* are made to rest on the top of this frame. Underneath the cage timbers *a* heavy planks are inserted as to cover the sump to prevent material from falling in d avoid the necessity of frequent cleaning. Without a ver, there is also the danger of animals falling into the mp and being drowned before they can be got out. This ver should be so arranged that it may be easily and quickly moved at any time.

84. **Illustration of Shaft Timbering.**—Fig. 60 shows e general form of construction of a three-compartment aft, the details of which have already been described. The ure shows a concrete walling *d* through the surface drift d subsoil into the hard pan, so as to form a water-tight int at this point. The excavation was first lined in the dinary way with timber frames and light board sheeting *c*, d the concrete *d* built up between this and the lining *h* of shaft. At *a*, a water-bearing stratum of rock was encoun-ed and shut off by the coffer dam *k* and the concrete fill- *f*. Below this point, the ordinary shaft timbering was tinued.

85. The sinking of a water shaft at Gilberton, Pennsyl-ia, furnishes a good example of the heavy timbers required en sinking through quicksand. It was estimated, in this e, that 6,000,000 gallons of water must be handled daily. is required a shaft measuring 22 ft. × 26 ft. 8 in., out to of timbers. For the first 87 feet below the surface, the aft passed through a peculiar formation composed of sand, y, gravel, shale, and boulders, and containing so much ter that it resembled quicksand. Fig. 61 is a plan of the bering near the surface and Fig. 62 an elevation of the bers, from the surface to the rock. As shown in Fig. 61

and in the upper part of Fig. 62, the timbering consisted of 20-inch round timbers with 6-inch lagging *b* on the outside; 4-inch planking *c* was spiked to the inside face of the round timbers *a*, and 12-inch square-timber frames *d* placed inside of these. Horn sets, or bearing, timbers *e*, 28 to 30 feet long, were introduced at intervals of 7 feet, center to center, making a total of twelve sets of these timbers. After the shaft reached rock, at a depth of 87 feet, only the inner lining was used. Several streams of water were tapped during the sinking, and coffer dams were built in the shaft

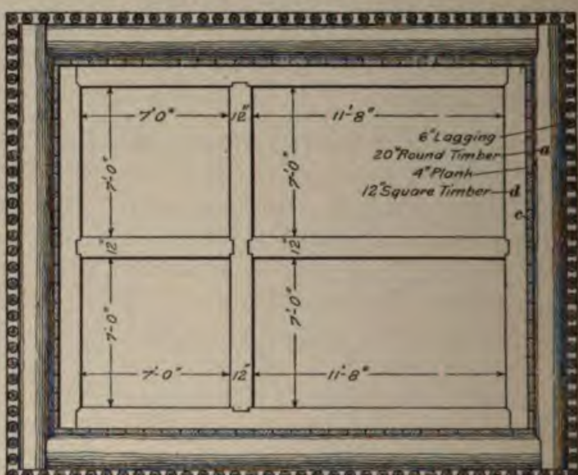


FIG. 61

at these points; the first was at a depth of 157 feet; the second, 250 feet; the third, 379 feet; and the fourth, 482 feet. All of these, except the last, were temporary, being maintained during the sinking only. The last, or permanent, dam consisted of ten sets of 12″ × 12″ timber placed skin to skin, the last set resting on the rock, which was dressed to a level bearing or seat, and 1 foot of oakum placed about the bottom of the ring, while the back of the timbers was lined with clay, thus forming a water-tight dam all around the shaft.

aming Timber Sets.—Several of the more ns of timber joints in common use are shown in Fig. 63. Each of these has special advantages that adapt it to different conditions. (*a*) is a simple square butt joint that requires no framing, but simply cutting the timbers to the exact length required. The butt joints are made to alternate, as shown. On account of its cheapness and simplicity, this form is adapted to shallow shafts when the lining is from 2 to 4 inches thick. A triangular corner piece is spiked in place after the timbers have been inserted and wedged. (*b*) is a simple half-and-half box joint made of timbers and capable of resisting heavy side pressure. The forms of joint shown at (*c*) and (*d*) are used when the timbers must be sprung into place, as in the timbering of certain

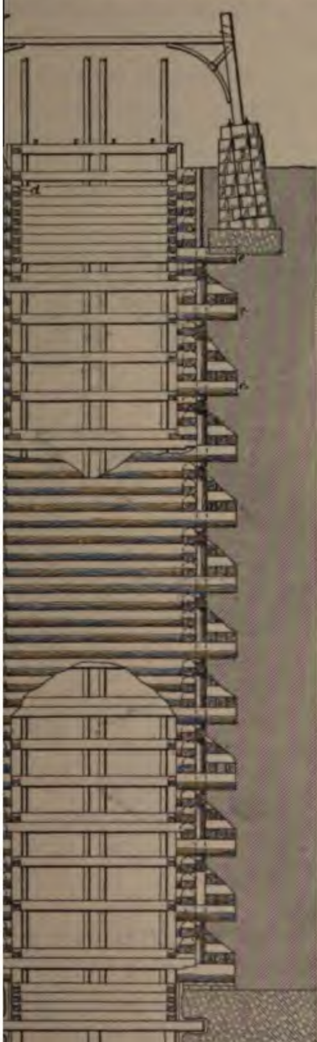


FIG. 62

hat are not self-supporting, and where the space for

lining is limited. At (*c*), the sets are made to alternate as in (*a*). (*d*) shows the same joint, except that it is not alternating; the boxing is continuous in the side timbers only, the end timbers being sprung into place. The feature of this joint is that the horizontal joints are broken, the end timbers being dropped one-fourth, one-third, or one-half below the side timbers, as shown. (*e*) is a more expensive box-and-tenon joint,

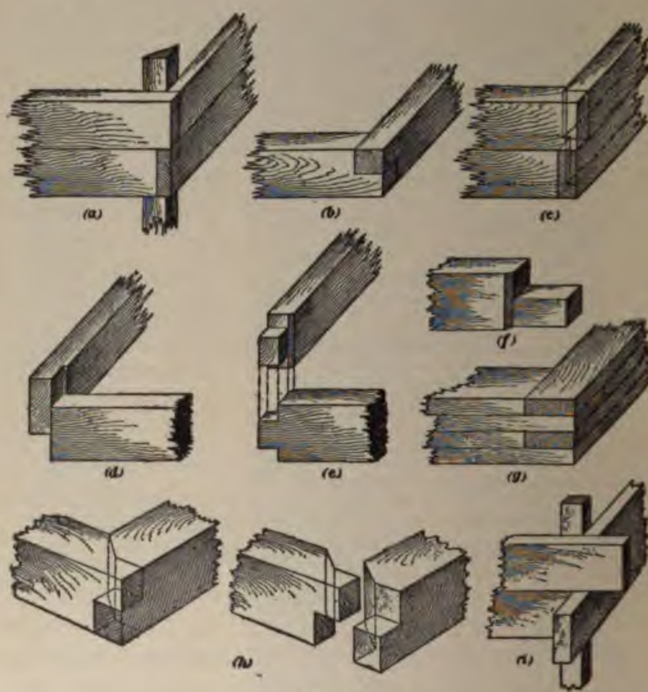


FIG. 63

but it is capable of withstanding great side pressure; here both the side and end timbers alternate so as to break joints. These timbers cannot be sprung into place but must be built up. At (*f*) is shown a form of joint similar to that at (*e*) except that the timbers are boxed half and half, making the end timbers, or end plates, level with the side timbers or side plates of the shaft.

The form of framing shown at (g) is principally used in ssing through quicksand, where the lining must be kept ose to the bottom of the shaft. (h) is an expensive but ry efficient joint capable of withstanding great side and d pressure. At) is shown what e called *horn sets*, *bearing* timbers. hese consist of the rdinary form of timer frame shown at), except that at tervals, the long nbers in each of

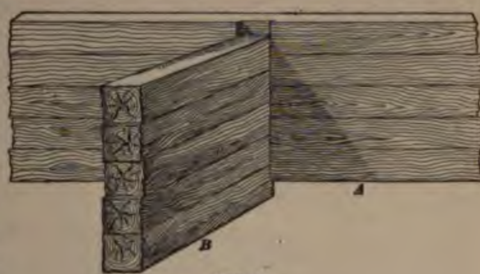


FIG. 64

o sets are extended so as to project from 18 inches to feet into the strata, giving a substantial support to the ing. The frequency of these horn sets depends on the aracter of the strata.

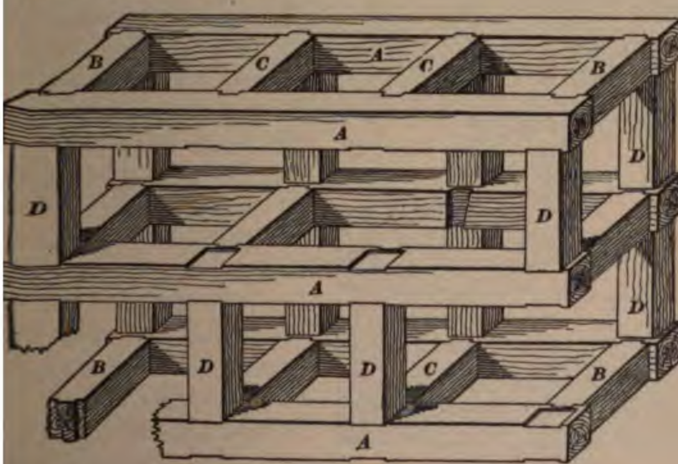


FIG. 65

Fig. 64 shows a method of setting the buntons B into e wall plates A. The ends of the buntons rest in grooves t $\frac{1}{2}$ inch deep in the wall plates, with which they break ints.

87. Square-set timbering is adapted to large shafts or heavy pressures. It is extravagant in the use of timber on account of both the size and the quantity of timber required. The form of joint is simple, as the timbers are for the most

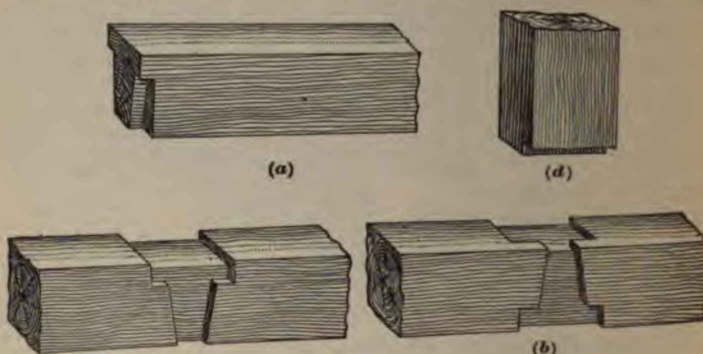


Fig. 66

part boxed slightly into one another. Fig. 65 shows the general construction in the timbering of a three-compartment shaft by square sets; in it, some of the timbers are omitted for the purpose of showing the form of joint employed. *A* are the wall plates, *B* the end plates, *C* cross-buntons, and *D* posts or punch blocks or studdles. The joints may be varied as shown in Fig. 66. With the joint shown in Fig. 66 (*b*), the cross-bunton is put in place from below. The advantage of this is that, if the timbering must be kept close to the bottom while sinking, the bunton going in from below can be left out at first, so as to allow more room for the workmen. Fig. 67 shows another method of joining end and wall plates, the post *F* being boxed into the plates both above and below. In this figure, a 2-inch strip *S* is shown

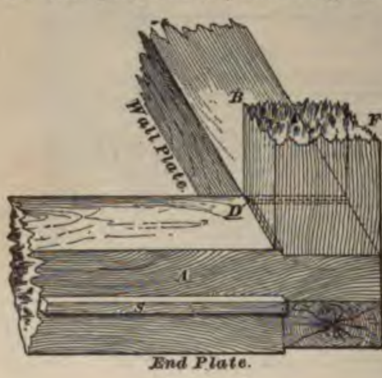


Fig. 67

h the lagging is to rest. Numerous other forms s are used in square-set timbering, but these will illustrate the principle, namely, that as little of the hould be cut out as possible, so as not to weaken er. In framing these timbers, regard must always o the manner in which they are put together in the When the timbering is done from top downwards the suspended by f hanger bolts f round-iron nt to a hook n one end and a thread and the other end,

FIG. 68

CURBS

A **curb** is a or foundation, ning of a shaft, erm commonly n England in tion with cir- afts lined with . The heavy or sill, at the ne shaft is also es called the curb, since in some cases the entire ing is hung from it.

term *curbing* is also variously used in different s and in different sections of the same country, ise to much confusion in describing shaft-sinking ns. Thus, in England, this term commonly means g that is placed on top of the curb, or shelf, made in as a foundation for the shaft lining. In different America, on the other hand, the terms *shaft curbing*, *bbing*, and *shaft lining* are used synonymously.

89. Wedging Curbs.—When the solid rock is reached in sinking, the size of the excavation is slightly increased and the top of the rock is carefully leveled off, so as to form a shelf, or curb, on which to rest the lining above. This shelf should not be blasted out, as this will shatter the under rock and make it impossible to make a tight joint between the rock and the shaft lining. A wedging curb *a*, Fig. 69, made of iron or wood is laid on this shelf, a tight joint between

Fig. 69

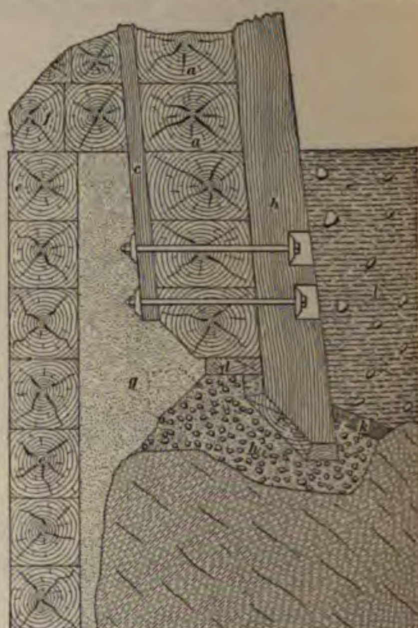


Fig. 70

the curb and the rock sometimes being made by means of a layer of cement under the curb and by ramming cement or concrete back of the timbers. If it is not desired to make a water-tight joint between the lining and the rock, a water ring similar to that shown in Fig. 57 is made in the wedging curb. Wedges *b* are placed between the curb and the rock, and on top of the curb the tubbing *c* is laid. The tubbing is tightened by means of the wedges *d*, which are backed by the concrete *e*.

In a rectangular shaft that is to be lined with timber, the ·dging curb usually consists of a horn set made of heavy tim-rs cut longer than the length of the shaft and laid into exca-tions made in the surrounding strata and on a cement base. Fig. 70 shows a more elaborate joint between loose ground d solid rock. The timbers *a, b, c, d* forming the lower rtion of the sinking shoe are left in place and the shaft ing *e* is built up inside of them. A puddling of clay or ment *k* is forced under the bottom of the shoe or caisson keep back the running material or quicksand *l*. Next a out *h* of cement and gravel is built against this clay and ound the point of the shoe. The space *g* between the side lining of the shaft and the grout *h* is filled in with ›rtland cement.

90. Supporting Curb.—It is sometimes necessary to nploy what is called a **supporting curb**. This consists a strong wooden or cast-iron curb supported on horizontal rs located in holes drilled in the strata and projecting into e shaft. These bars are in a horizontal plane and furnish required support for the curb laid on them. The masonry it is to form the shaft lining rests on this curb. This angement is generally temporary, and used when the ıft lining is built in sections.

MASONRY AND METALLIC LININGS

91. Masonry shaft lining, which may consist of brick, k, or concrete, is used where timber is scarce or where the racter of the strata is such as to render timber lining practicable. A section only of a shaft is sometimes thus ed while the ordinary timber lining is used in the greater rt of the shaft. These linings are usually laid on a wedg-r curb and are carried upwards in sections, as shown in g. 71. Each section is laid on a ring *a* of cast iron or nber resting on a temporary shelf or seat *b* cut in the rock. s the lower sections are built up, the shelf *b* supporting e masonry above is cut away in places and the masonry low carried up to furnish the necessary support for the

upper section. In this manner, all the shelf is finally cut away and replaced by the masonry of the lower section.

92. Tubbing is an English term applied to the metal, or sometimes to the timber, lining of a circular shaft, and is particularly used when such linings are employed to keep water from flowing into a shaft. The three kinds of metal tubbing are: (1) that which is made in sections with outside flanges and is simply wedged firmly into place by wedges placed between the tubbing and the wall of the shaft; (2) that which is made in sections and bolted together on the inside both at the vertical and horizontal joints; (3) that which is made up of complete rings of cylinders bolted together by means of horizontal flanges.

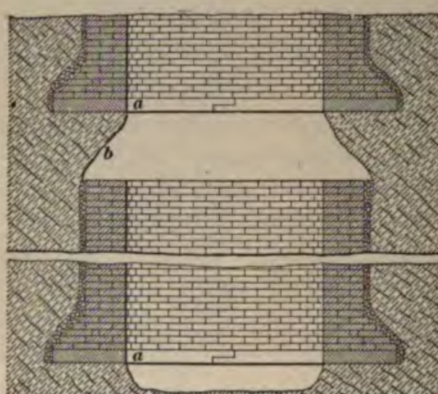


FIG. 71

The metal tubbing, Fig. 72 (*a*), consists of cast-iron segments varying in height from 18 to 36 inches according to the pressure to be resisted. The segments are flanged at top, bottom, and ends and ½-inch pieces of pine are put between them as they are put in place, thus making tight joints both horizontally and vertically. To prevent breaking the metal lining by the pressure of air or gas behind it, the metal is perforated; these holes are loosely plugged, so that any particular pressure coming on them will force out the plugs. Fig. 72 (*b*) shows a method of walling a circular shaft with brick, the brick being laid on a cast-iron wedge curb *s*.

Wood tubbing may be of two kinds: (1) planks 2 or 3 inches thick placed vertically and having beveled edges like barrel staves; (2) thick blocks similarly beveled and

ertically. Fig. 72 (c) shows an example of plank

The planks have urves m placed in- m and spiked to he curves are kept *punch blocks n* and together and fast- the shaft sills l by gers r. The sec- the shaft (b) and shown supported k bench while the bbing is being put below. When a s been lined up to bench, this is cut d the metal tub- ned to the other of the shaft lining ll metal sections *osers*.

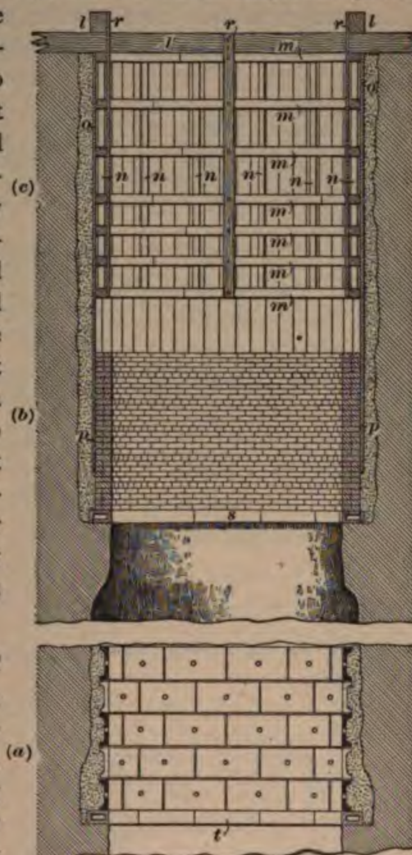


Fig. 72

Thickness of nd Masonry Li- The following for- given by Mr. W. for calculating er thickness for tubbing, or for or brick lining.

$$t = \frac{w\,h\,d}{2(r + w\,h)}$$

t = thickness of lining, in inches;
d = internal diameter of shaft, in inches;
h = head of water, in inches;
w = weight of cubic inch of water $= \frac{62.5}{1,728} = .0361$ lb.;
r = $33\frac{1}{3}$ per cent. (one-third) of crushing load per square inch of material used.

The crushing strength of the material used should be determined in each case by experiment, but the following may be used as a fair average value:

	Pounds Per Square Inch
Crushing strength of cast iron	80,000
Crushing strength of brick laid in lime mortar	1,000
Crushing strength of brick laid in cement and lime	1,500
Crushing strength of brick laid in best cement mortar	2,000
Crushing strength of concrete made from Portland cement and 1 month old	1,000
Crushing strength of concrete made from Rosendale cement and 1 month old	500
Crushing strength of concrete made from Portland cement and 1 year old	2,000
Crushing strength of concrete made from Rosendale cement and 1 year old	1,000

Example.—What should be the thickness of tubbing for a shaft 13 feet in diameter at a depth of 800 feet: (*a*) for cast iron? (*b*) for brick, assuming a mean crushing strength of 1,500 pounds per square inch? (*c*) for concrete made from Portland cement and one month old?

Solution.—

$$(a)\quad t = \frac{.0361 \times 800 \times 12 \times 13 \times 12}{2\left[\frac{80,000}{3} + (.0361 \times 800 \times 12)\right]} = \frac{27,031}{26,666 + 347} = 1 \text{ in. Ans.}$$

$$(b)\quad t = \frac{.0361 \times 800 \times 12 \times 13 \times 12}{2\left[\frac{1,500}{3} + (.0361 \times 800 \times 12)\right]} = \frac{27,031}{500 + 347} = 31.9, \text{ say } 32 \text{ in. Ans.}$$

$$(c)\quad t = \frac{.0361 \times 800 \times 12 \times 13 \times 12}{2\left[\frac{1,000}{3} + (.0361 \times 800 \times 12)\right]} = \frac{27,031}{333\frac{1}{3} + 347} = 39.7, \text{ say } 40 \text{ in. Ans.}$$

94. Metallic Lining Supported From the Surface. When, on account of the presence of water in the shaft, it is necessary to build up the entire lining by adding successive sections at the surface, the method illustrated in Fig. 73 is used. A tight joint between the lining and the underlying rock is made by means of a *moss box;* this consists of two rings of lining *a*, *b*, each of which has a flange turned

outwards at the bottom and inwards at the top. The ring *b* slides over the ring *a* and the annular space between the ring *a* and the rock is filled with moss *c*. When the lower section *a* reaches the rock, the weight of the overlying sections forces the section *b* down on the moss, compressing it between the two flanges *d* and *e* and thus forming a water-tight joint. The sections of the tubbing above the moss box are bolted together by means of flanges that turn inwards, while a tight joint between the flanges is made by means of a thin strip of lead. The weight of such a lining is enormous and in order to successfully lower it, a diaphragm *f* is fastened to the flange of one of the segments just above the moss box. In the center of this diaphragm is a tube *g*; as the lining is being lowered the weight of the lining forces the water through this central opening. The buoyant effect of the water and the resistance that the tubbing meets in sinking through the water are so great that the weight of the tubbing is largely counterbalanced. After the metal lining is in place, the space between it and the rock is usually filled in with concrete; as soon as this is set the water can be pumped from the inside lining.

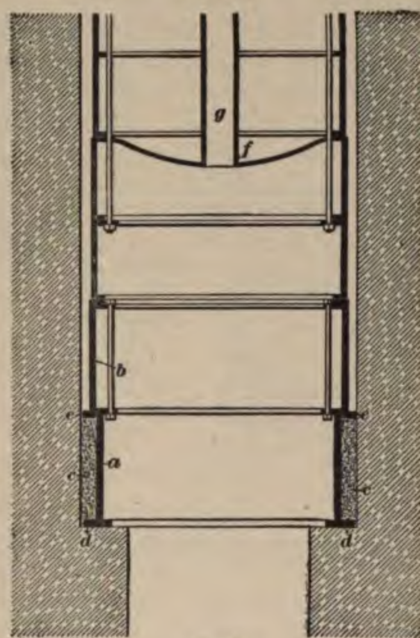
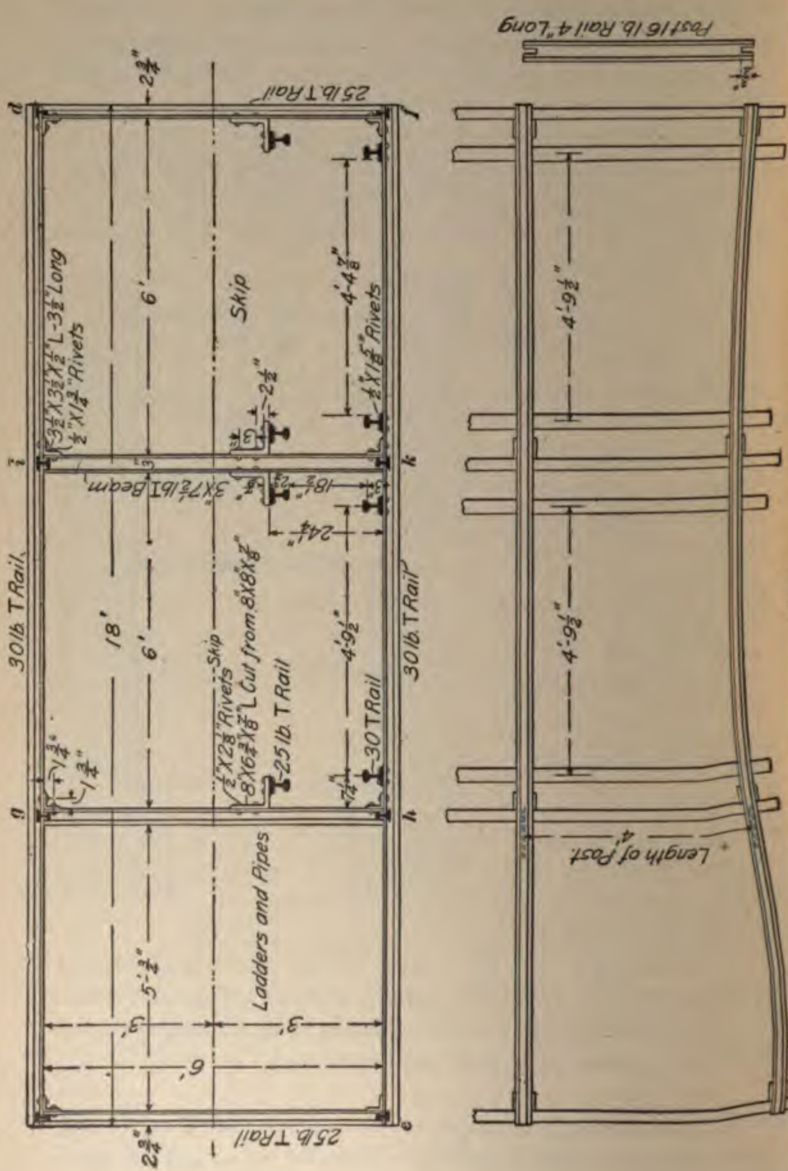


FIG. 73

95. Steel Shaft Lining.—The use of metal for lining shafts has, until recently, been restricted to circular shafts, in which iron tubbing was employed. Steel has now been


30 lb. T Rail
30 lb. T Rail
25 lb. T Rail
25 lb. T Rail
Skip
Skip
Ladders and Pipes
18'
6'
6'
5'-½"
3'
3'
6'
4'-9½"
4'-9½"
4'-4⅞"
24¼"
3"X7½ lb. I Beam
25 lb. T Rail
30 T Rail
Length of Post 4'
Post 16 lb. Rail 4" Long

introduced and used successfully in the lining of rectangular shafts. The method adopted at Ely, Minnesota, by the Oliver Iron Mining Company, and shown in plan and elevation in Fig. 74, has been to use rectangular frames, or sets, after the manner of timber frames. These are placed at suitable intervals, with *studdles* between to serve as posts or uprights. These frames have been lagged most successfully with corrugated steel. Flat plates stiffened by angles could be used, but for equal strength are more expensive. There is no framing of the sets, as in the use of timber, but the parts are put together, after the manner of ironwork, by riveted angle bars. Steel rails weighing from 25 to 30 pounds per yard are used for the wall and end plates, while 3-inch, 7½-pound I beams are employed as center girts to divide the compartments of the shaft. The members of the set are connected together by angle pieces, or knees, 3½ in. × 3½ in. × ½ in., and 3½ inches long, each angle being secured by two ½-inch rivets in each leg. The studdles are pieces of 16-pound rail 4 feet long, the ends being slotted, as shown in the figure, to receive the flange of the wall plate.

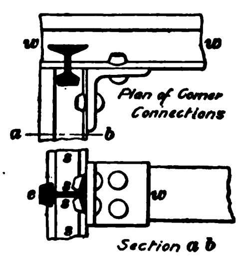


FIG. 75

Fig. 75 shows a detail of the connection between the wall and end plates and the studdle at the corner of the shaft. *w* is the wall plate, *e* the end plate, and *s* the studdle. The studdles are not riveted, but held firmly in position by the slot in each end, in which rest the flanges of the wall plates, while the head of the rail rests on the web of the end plate between the head and flange of that rail. In this position, it is held firmly from moving in any direction. No lagging is used, except where the strata require the support of the lining. For lagging, old wire ropes interlaced with wooden lath have been used; but with the view of retarding the spread of fire, metal lath or corrugated steel plates may be used.

In sinking, the steel sets are suspended by hangers in the same manner as are timber sets. These hangers, Fig. 76,

consist of simple bar iron having at each end a hook that passes over the flanges of the wall plates, a wedge being used as shown. In a deep shaft, the weight of the steel lining is taken up at intervals by bearers made of 30-pound rails set in hitches cut in the rock. The ends of the bearing pieces extending into the hitches rest in cast-iron

FIG. 76

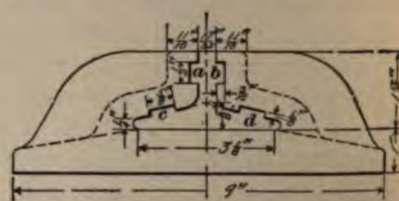


FIG. 77

chairs, Fig. 77. Small steel wedges are driven into the openings a, b, c, d to hold the chair in position on the rail.

In order to give a firm footing to the steel set resting on

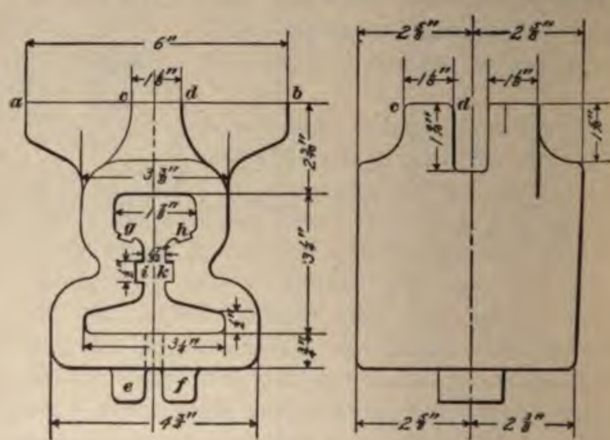


FIG. 78

the bearers, cast-iron chairs of the form shown in Fig. 78 are used. These are slipped on the steel plates before the latter are placed in position; and when these chairs have been

adjusted in their proper position, small steel wedges are driven in the openings g, h, i, k.

96. Concrete Lining With Expanded Metal.—The use of concrete as a shaft lining is rapidly gaining favor. This method has also been successfully used in relining shafts. The following are the details of the process used by the Lackawanna Company in relining a shaft near Scranton, Pa.

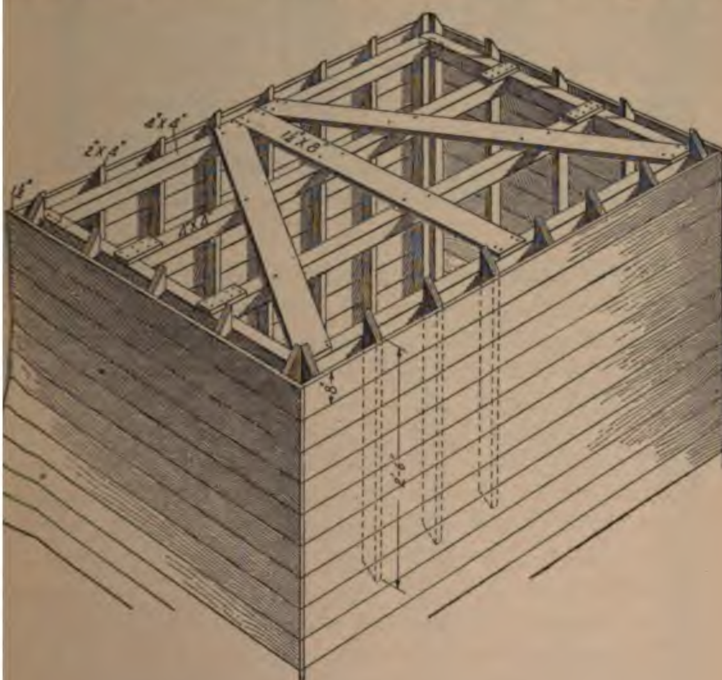


FIG. 79

Concrete in the proportion of one part of cement, two parts of sand, and five parts of broken stone was used; the broken stone is replaced at some places by fine ashes from under the boiler, from which the large cinders are removed, or by slate or bony coal. These proportions were varied to suit conditions, the concrete being made strongest at points of greatest pressure. The thickness of the lining varies from

8 inches to 2½ feet, and as the shafts that were relined had originally been lined with an outer and inner lining, with a puddled space between, the inner lining and the puddled material were removed and replaced by the concrete, the

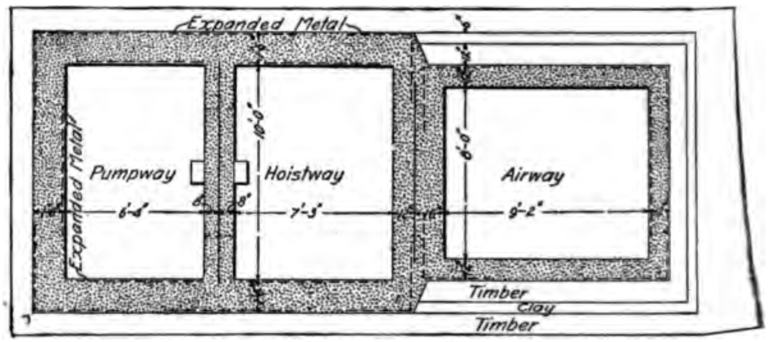


FIG. 80

outer lining serving to hold back the walls as the work of laying the concrete progressed. A box made of 1¼″ × 8″ timber, well braced, Fig. 79, fitting closely against the inner lining and of the same size as the shaft compartment was used as a form around which the concrete was placed. The work was begun on the rock at the shaft bottom, and carried upwards to the surface of the ground. The sheets of expanded metal were $\frac{3}{16}$ inch thick and 6 ft. × 8 ft. in size and overlapped at each meeting point. They were placed along the sides and ends and at the corners as shown in Fig. 80 by the broken lines. The shaft buntons were taken out and replaced by concrete, the concrete partition being continuous from bottom to top of shaft, except for oval openings left to permit examination of the guides, as shown in Fig. 81. These concrete partitions, as

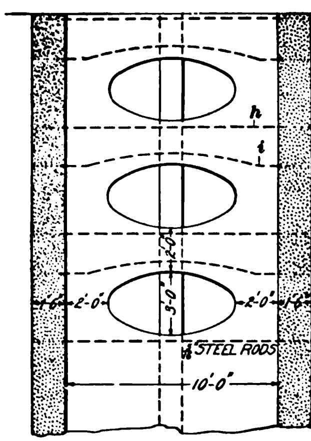


FIG. 81

:ll as the concrete lining, are stayed by rods *h*, *i* set in the ncrete, as shown by the dotted lines in Fig. 81. To serve fastenings for the cage guides, bolts were set into the icrete partition.

SPECIAL SHAFT WORK

)7. **Retimbering a Shaft.**—As a rule, the shaft lining uld last until the shaft is abandoned. It frequently pens, however, that, owing to poor timber or bad ground, haft will need to be relined in places, or it may be irable to replace the entire lining of an old shaft.

n the retimbering of a shaft, the timbers are removed y as new ones are put in their place. If the entire shaft to be retimbered, the work is best performed from the tom upwards. Starting at the bottom, the old timbers withdrawn two or three sets at a time, according to the tracter and condition of the strata, and solid substantial mes put in their places. It will often be necessary to port the curbing above by temporary blocks or posts set der the old frames and standing on the new ones. The sition of these blocks can readily be changed as the new bers are inserted. Care must be taken in this work to np good material behind the timbers as the latter are ilt up, so as to leave no cavities between the lining and strata. The same provision must be made for the drain- e of wet strata, as mentioned in reference to sinking. A ffolding is carried up the shaft for the workmen to stand as the work advances. Support for the scaffolding may found in the center buntons and cleats spiked to the ft lining below, or the platform may be hung from the ancing work.

)8. **Enlarging Shafts.**—Though a shaft should always sunk sufficiently large to meet every requirement, it en happens, in the later development of a mine, that the put cannot be maintained on account of the increased gth of haul without increasing the size of the mine car, ich generally requires also, the enlargement of the shaft.

The term *widening* is generally applied to any increase in the sectional area of a shaft by increasing the length or the width of the shaft, or both. As a rule, hoisting ceases during widening, but the shaft may be widened at night without interfering with the hoisting during the day, an auxiliary sinking cage being then used.

The plan ordinarily followed is to widen on one side or one end, as by this means timbering already in place is made use of, the alinement of the shaft is maintained, excavating is done easily, and less readjustment of hoisting sheaves, stops, etc. is necessary.

Fig. 82 represents the top of a shaft that is to be enlarged by increasing its length. The manway *m* is to remain

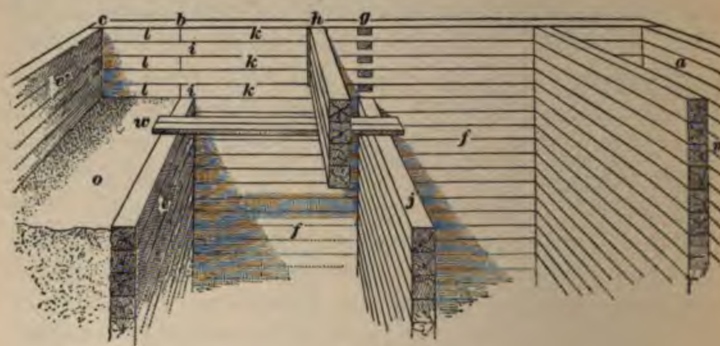


FIG. 82

unchanged, the end wall opposite to the manway being moved out from *b* to *c*. The end plates *e* are to be used again. The center partition *j* dividing the hoistways *f*, *f* is to be moved from *g* to *h*, the distance *g h* being one-half the distance *b c*, so as to make the hoisting compartments the same size. It is not customary to make the partition between the hoistways solid, but simply to use occasional cross-buntons, excepting where there is great pressure on the side timbers. Each alternate wall plate is cut at *h*, so that its end will rest against the center bunton *h*, and a new piece *i*, reaching from *h* to *c*, is substituted for the part cut out. The old center buntons *j* are sawed close to the wall plates

d may be used again for short lengths at *l*, the buntons *h* ing new timbers. The alternate wall plates *k*, remaining position, are cut square on the line *b*; the short fillers *l* tt against these and are framed into the wall plates at *c*. is a temporary working platform resting on the old end ates and center bunns and passing underath the new center intons. The material excavated from the ace *o*, as the end ates *e'* are removed. his material is hoisted the surface by a mporary block and oisting engine, or by e permanent hoisting igine.

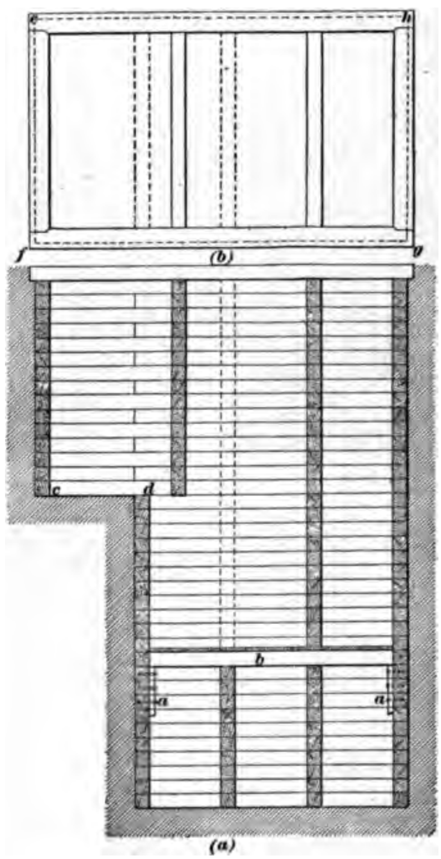


FIG. 83

99. A slightly different method of carryg on the work is lown in Fig. 83. eats *a* are nailed on e old lining and bunis *b* placed on them ross the shaft; on ese is built a platform which the men work. ie enlarging is begun the surface and card downwards, a secn usually about 8 feet gh being taken out m each platform. The drillers work on the bench *c d* and ad the waste directly into cars on the cage. The end *e f* is nbered and backed as in sinking a new shaft. The sides *e h* id *f g* are timbered as shown. The timber joints at the

corners g and h are left undisturbed, each alternate side timber being taken out for part of its length and a new timber dovetailed in between it and timbers above and below, the parts being joined by a feather-edge joint. When both the length and breadth of the shaft are to be increased, an entirely new shaft lining will be required; the excavation in this case may preferably be made on all sides of the shaft instead of on one side only.

In some cases, shafts have been enlarged and retimbered very successfully by filling the shaft to the surface with cinders and ashes, using such a platform as is shown in Fig. 83 for a foundation for the filling. Then commencing at the surface the old timbering is taken out, the shaft enlarged, if desired, and new timber put in place as if it were a new shaft. This is a costly procedure, but is often cheaper ultimately than endeavoring to use one or more sides or ends of the old shaft.

100. Deepening Shafts.—There are several methods of **deepening shafts** when it is desired to extend them to a lower level than the one being worked. The following three are those most commonly used.

1. *First Method.*—A false bottom of heavy timbers is provided in the sump as a resting place for the cage, and sinking is begun on the bottom of the sump. When the new seam is reached, a new sump is made, new guides are extended from the bottom upwards to meet the old guides, the false bottom is removed, and the cage ropes spliced, or new ones of sufficient length to allow the cages to hoist from the lower seam substituted for the old ropes. This method is used often where material is being hoisted during the day and sinking done at night. A small sinking cage is slung under the regular cage or a bucket is used instead, the material being hoisted to the old shaft-bottom level and there taken back into the old workings and gobbed. The disadvantages of this method are that all the water from the old sump drains through the false bottom and down on the sinkers at their work, and there is always danger of materials falling down the shaft on the sinkers.

Second Method.—At a short distance from the shaft
1 and on a passageway that is not much used, a steep
1 *b*, Fig. 84, or small shaft is sunk, the depth of sinking
ling on the amount of rock necessary to be left as a
t under the old sump while the deepening proceeds.
foot of the slope a level heading *b c* is first driven to
posite face of the shaft; the roof of this heading is
ly timbered by setting the collars in hitches cut in
es, before the
of excavating
aft below is
nced. When
done, the ex-
n is begun
rried down in
line with the
above, the
ial being re-
by a hoisting
operated by
ass or tempo-
isting engine
at some point
e head of the
The further
on of sinking,
ng, etc. is the
as that pre-
described.

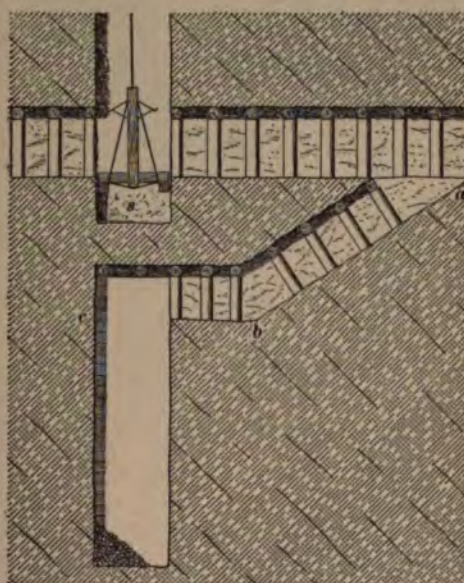


FIG. 84

he sinking is complete and the shaft timbered, the main
is drained and the two shafts connected by driving
s from below, or downwards from the bottom of the
rom a strong temporary staging erected at *c*.

Third Method.—Fig. 85 shows the method of deepen-
haft while the upper part is in use, by opening only
rtion of the shaft area not under the hoistway for a
e of 12 to 15 feet, and then widening it out the entire
the main shaft. This leaves a roof of rock (*pentice*)

that shields the men. When another lift has been sunk, the pentice is cut away and another started for the next drop. The hoisting is done by an underground engine or by bucket and windlass.

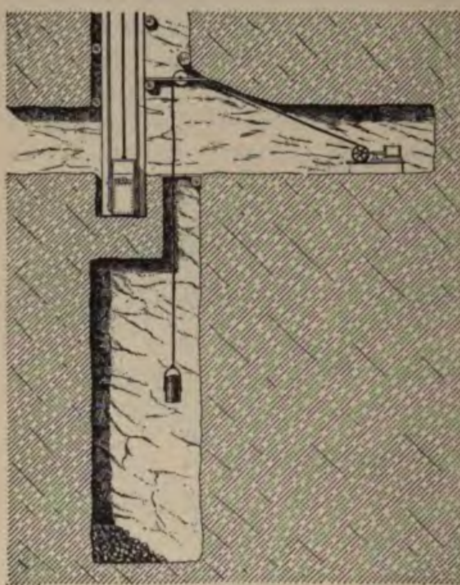


FIG. 85

101. Upraising. It is often necessary, in order to gain time, to drive a shaft upwards from the inside workings as well as downwards from the surface. At times, shafts are driven entirely from below, this being often the case with escape or air-shafts, which are frequently started from the workings below. **Upraising,** or driving upwards, is more expensive than sinking, so far as the labor of driving is concerned; but there is a saving when the work is wholly performed by upraising, as it is then not necessary to set up a sinking plant on the surface, and an engineer's wages are also saved. The material is generally stowed in the old workings below, but sometimes when room is not available it is sent to the surface. Before commencing to drive upwards, a careful survey is made to establish the four corners of the shaft in the mine immediately under the surface location. Four iron pins are driven in the bottom to mark these corners. If necessary, posts or timber cribs are set to secure the roof around the place before blasting is begun. When the excavation has proceeded upwards 8 or 10 feet in the roof, the bottom is cleaned up, the pins located, and the shaft tested for alinement by hanging

b-bobs in each of the four corners. Timbering is then n by first setting a heavy square frame *f*, Fig. 86, in oof, resting on substantial posts and sills, as shown in igure. The inside measurement of the frame must spond to the size of the shaft in the clear when tim- . This frame is exactly located by means of the plumb- hanging over the four points previously established, s then firmly wedged in place. The timbering of the is built up on this frame after the ordinary manner of timbering. The ring is carried ose to the roof acticable, and a ion is carried viding the shaft two compart- s. This par- may later be in the operation e shaft as one permanent par- s, and should be d accordingly. heavy bulkhead v constructed at bottom of the and a chute ged under the

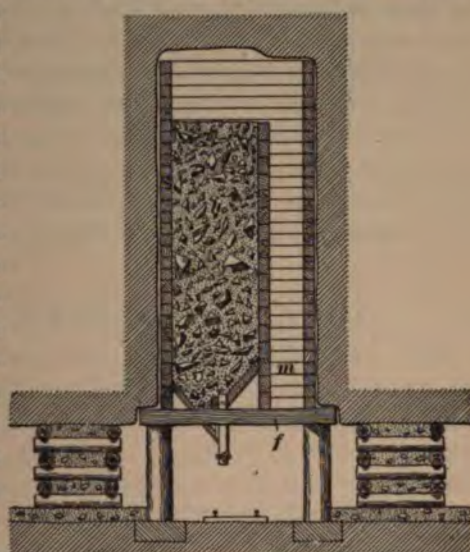


Fig. 86

r compartment *h*, by which the loose material excavated and thrown into this compartment may be drawn and d as required. To control the descent of the loose ial in this compartment, a door is arranged at the foot chute. The compartment *m* serves the double purpose manway and air-shaft, and for this purpose it is divided temporary partition. A ladder is constructed in the vay, by which the workmen travel up and down.

the operation of upraising, the workmen ascend the vay by the ladder and stand on a temporary platform, or

on the loose material that is allowed to fill the compartment *h*. The material is drawn from this compartment only as is required to furnish good standing room at the face. In upraising, the ventilation of the shaft is always more or less difficult, owing to the tendency of the smoke and hot bad air to remain at the top. The air compartment may be connected, by a box, to the main air-course while the manway is open to the return, or vice versa; by this means, a fair current of air may be maintained at the top of the shaft or upraise. At times, a small blower is used to blow the air into the face. When compressed air is used to operate the drills, there will be air sufficient for the ventilation of the upraise without making other provision. The timbers required must be taken up the manway or the air compartment. When blasting, the manway and air compartments are covered with heavy planks, to avoid the material loosened by the blast falling down the shaft and breaking the ladders or partitions.

CONTRACTS FOR SHAFT SINKING

102. A bore-hole record of the various strata to be passed through is usually available, and the sinking contractor therefore knows what he must expect and bids accordingly. His contract generally requires him to sink a certain distance, or to a certain coal or ore body, to properly timber the whole shaft, and to put heavy timber, horn sets, water rings, etc. where he is directed by the owner. The sinker is often required to give bond for faithful performance of work and only a certain percentage of the price agreed on per foot is paid at the end of each month, the remaining part being withheld until satisfactory completion of the contract. In order to protect the company against the filing of liens for unpaid labor or material, the contractor is often required to present all bills for material used in the prosecution of the work to the company; and to furnish the company with a correct pay roll of all labor employed each month; such bills and pay rolls to be paid directly by the company and charged to the contractor's account, and deducted from any amount due him on the contract.

The head-frame, engines, pumps, and explosives may be furnished by either party as may be agreed on. The owner or operator of the property usually furnishes the power and men for hoisting the material excavated and any water above a certain limited amount, the lumber, and other supplies, such as cement, nails, etc. The contractor usually furnishes the drills and other tools and the drillers and laborers.

When inviting bids for a contract for sinking a shaft, the company is expected to provide a set of specifications giving such information as may be in their possession that will enable the bids for the work to be made intelligently, and stating the exact requirements that will afterwards form part of the contract.

A date is set by the company when all the bids received will be opened, examined, and the contract awarded, often "to the lowest responsible bidder." The company usually, however, reserves to itself the right to reject any or all bids. Where a bond is required, it is sometimes requested that the nature of the bond be submitted with the bid for the approval of the company.

No form of contract can be given that will be of universal application, but the following form will serve as a guide in drawing up such contracts.

This Agreement made this_____day of____________A. D. 19___, between________________of______________, in the County of ____________and State of______________, party of the first part and__________of______________, in the County of__________, State of____________, party of the second part.

The party of the first part, for and in consideration of the agreements hereinafter contained and for the further sum of one dollar ($1) to him in hand paid, the receipt whereof is hereby acknowledged, agrees to sink a shaft upon the property of party of the second part located in____________, in accordance with the plans and specifications furnished by the party of the second part and which form part of this agreement, and which shall remain the property of the party of the second part, and to turn over the completed work within the time hereinafter specified, free from all liens or encumbrances whatsoever, for the final inspection and acceptance of the party of the second part.

The party of the second part agrees to furnish the party of the first

part from time to time, as requested, such further plans or explanations as may be necessary to detail and illustrate the work to be done, and they shall form part of the contract, so far as they may be consistent with the original plans and specifications.

ART. I. DIMENSIONS.—The shaft is to be__________ (_____) feet long and__________ (_____) feet wide in the clear, and in order to keep the shaft true to size and plumb, six lines must be suspended, one in each corner and one in the middle on each side, as directed by the party of the second part, and no points in the ends or sides of the completed shaft shall project outside these lines. The corners to be well squared, and all loose rock in the walls of shaft must be trimmed down and made secure as the work advances.

ART. II. DEPTH.—The depth of shaft to be about__________ (_____) feet, or from the surface to a point__________feet below the __________vein or seam, the twelve feet below the__________vein or seam being for a sump.

ART. III. WATER.—The party of the first part agrees to make all lodgments or sumps for water where and when required and rings for conducting the water to the sump. to make all platforms for setting of pumps and roofs for protecting the same from falling debris from blasts or otherwise, and to do all necessary work in the shaft for the protection of machinery and pipes placed therein, as directed from time to time by the party of the second part.

ART. IV. WORK.—The party of the first part agrees to prosecute the work with all possible vigor and despatch, and in a good workmanlike manner. As many men must be worked on a shift as the party of the second part thinks proper and three (3) shifts of eight (8) hours each must be worked in every 24 hours except Sunday. Steam or air drills will be allowed after the first 25 feet, except in rock where in the judgment of the party of the second part it will be detrimental to the shaft. If steam or air drills are used, at least________machines must be used at one time when required.

ART. V. Should the party of the first part at any time refuse or neglect to supply a sufficiency of properly skilled workmen, or of materials of the proper quality, or fail in any respect to prosecute the work with promptness and diligence, or fail in the performance of any of the agreements herein contained, the party of the second part shall be at liberty, after________days' written notice to the party of the first part, to provide any such labor or materials, and to deduct the cost thereof from any money then due or thereafter to become due to the party of the first part under this contract; or to terminate the contract and to enter upon the premises and take possession, for the purpose of completing the work comprehended under this contract, of all materials, tools, and appliances thereon, and to employ any other person or persons to finish the work, and to provide the materials therefor and in case of such discontinuance of the contract the party of the first

part shall not be entitled to receive any further payment under this contract until the said work shall be wholly finished, at which time, if the unpaid balance of the amount to be paid under this contract shall exceed the expense incurred by the party of the second part in finishing the work, such excess shall be paid by the party of the second part to the party of the first part; but if such expense shall exceed such unpaid balance, the party of the first part shall pay the difference to the party of the second part. The expense incurred by the party of the second part as herein provided, either for furnishing materials or for finishing the work, and any damage incurred through such default, shall be audited and certified by a board of three arbitrators, each party selecting one and these two choosing a third, and the certified findings of such board of arbitrators shall be conclusive upon the parties. If the party of the first part or any of his employes conduct himself improperly or does anything to injure the work, he shall be discharged immediately.

ART. VI. LABOR AND MATERIAL.—The party of the first part must furnish all necessary help and material for the execution of the work, except as hereinafter mentioned, and render not later than the______ day of each month the time and wage rate per day of each man and boy that has worked for him on said shaft during the previous month.

And the said party of the first part hereby authorizes and directs the party of the second part as far as the party of the second part shall be indebted to the party of the first part, to pay on the______day of each month on a pay roll to be made out and approved by both the parties of the first and second parts, such sums as may be due as stated in said pay roll to the employes of the first party, and to charge the total of the amounts so paid to the account of first party, deducting such amount from any money due or that may become due later on the contract.

ART. VII. MACHINERY.—The party of the second part agrees to furnish machinery and power and a hoisting engineer for hoisting from the shaft, and when the amount of water exceeds__________ (______) buckets per hour, he will furnish pump and one machinist to assist the party of the first part to put the pump and pipes in place. He will also furnish iron and ties for track to dump and cars for same, and all lumber and nails required inside the shaft.

ART. VIII. TIMBERING.—The work of timbering, putting in buntons, guides, and so forth, will be done by the party of the first part, and if not put in satisfactorily to the party of the second part, the party of the second part reserves the right of stopping the party of the first part and his men, and of putting them in himself with his own men, at the expense of the party of the first part.

ART. IX. PAYMENT.—The said party of the second part hereby agrees to pay to the said party of the first part in the manner and at the rates following, to wit: the sum of__________dollars (______)

per lineal yard for each and every yard of surface or drift sunk, and ____________dollars (________) per lineal yard for each and every lineal yard of rock driven. Gravel and boulders do not constitute rock, in the meaning of this contract, except boulders of considerable size and frequency requiring continued blasting. An occasional boulder requiring to be blasted is not to be classed as rock.

The party of the second part shall be given monthly estimates of the amount of work done by the party of the first part.

And the said party of the second part further agrees that he will pay the said party of the first part on or before the______________(______) day of each month for the work done during the preceding month at the prices hereinbefore agreed to be paid for said work as specified, and that he will after paying the men employed by the said party of the first part at the times and in the manner hereinbefore specified, the amounts due them as shown by the pay roll to be made as aforesaid; provided, however, that the said party of the first part shall be entitled under this contract to receive for work done an amount equal to the amount called for by said pay roll, and provided further that in no case shall the said party of the second part be liable for services rendered by any person or persons employed by the said party of the first part to any greater extent or amount than there shall be due the said party of the first part for work done as heretofore agreed.

And further, the said party of the second part shall have the right to retain from the monthly payments due first party and hereinbefore agreed to be made upon each monthly estimate, the sum of ten (10) per cent. of such estimate, for the first hundred feet or fraction thereof, seven and one-half ($7\frac{1}{2}$) per cent. for the second hundred feet or fraction thereof, five (5) per cent. for the third hundred feet or fraction thereof, and two and one-half ($2\frac{1}{2}$) per cent. for any fraction of the remaining distance until the completion of said shaft, satisfactorily to the party of the second part. The amount so retained to be paid to the said party of the first part upon the acceptance of the work by the second party when the shaft shall have been completed in accordance with the terms of this contract and to the perfect satisfaction of the party of the second part.

ART. X. ACCEPTANCE OF WORK.—Upon the completion of the work and within the time hereinbefore specified, the party of the first part shall signify, in writing, his readiness to turn over the work for the final inspection and acceptance of the second party; such inspection and acceptance to be made by the duly qualified officers or agents of said second party, within__________days after the receipt of the notice that the work is ready for them.

The party of the first part shall not remove any of the machinery, tents, tools, or other implements used in the work from the ground, until after receiving the written acceptance of the work by the said second party, which machinery, tents, tools, and implements shall

remain subject to attachment by said second party in case of a deficit in the final settlement.

After the final inspection and before accepting the work, the party of the second part shall have the right to advertise for any unpaid claims for labor or material used in the work, a certain length of time as may be required by law, before writing the final acceptance of the work, permitting the removal of the chattels belonging to the first party. In case the total amounts paid by the second party for labor and material and chargeable to the first party shall exceed the total amount to be paid for the work under the terms of this contract, the said second party shall have the right to attach and hold the aforesaid chattels, machinery, tents, tools, and other implements used during the prosecution of the work, to recoup the amount of such deficit.

ART. XI. RESPONSIBILITY.—The party of the first part will be responsible for all accidents on his own part, or on the part of any one of his men, and will save harmless the party of the second part from all claims for damage for injuries received by any of them in the prosecution of the work.

The party of the first part will provide for the ventilation of the shaft during sinking and will see that all the requirements of the Mine Law are strictly complied with.

In witness whereof the parties of these presents have hereunto set their hands and seals this________day of________________19__

____________________________[SEAL].

____________________________[SEAL].

METHODS OF WORKING

(PART 1)

DEVELOPMENT OF COAL MINES

INTRODUCTION

1. The development, or exploitation, of a mine is the productive working of the mine as distinguished from its exploration or prospecting. The method adopted for working a bed of coal depends mainly on the character, thickness, and inclination of the coal bed and the character and thickness of the cover over the coal. The conditions in any given coal field therefore should determine the best method of mining for that field. Each mining region and each coal seam in a mining region often present different problems; consequently, there are a number of methods of mining coal and no one method will answer for all mines.

SURFACE STRIPPINGS

2. Conditions Favorable to Stripping.—Coal beds are sometimes found under a thin covering of earth or rock so that it is possible to *strip* the coal; that is, to remove this covering and then blast the coal directly from the bed as in quarrying.

The conditions that determine when stripping is advisable are the quality and thickness of the coal bed and the character and amount of covering to be removed. No definite

rule can be given that will determine absolutely when stripping is practicable, but the method has been carried on with the covering varying from a few feet up to as high as 125 feet. This method of mining becomes impracticable when the cost of stripping and mining exceeds the value of the product, and the bed must then be opened by means of a drift, a shaft, or a slope.

3. **Anthracite Strippings.**—The most extensive coal strippings in the United States are those in the anthracite

FIG. 1

fields of Eastern Pennsylvania, where beds of coal, often from 40 feet to 60 feet in thickness and sometimes even more, are steeply inclined at the outcrop or lie in basins above which there is little cover; a large amount of coal can thus be easily reached by the removal of a comparatively small amount of overburden. A rule often given in connection with these strippings is that the bed can be stripped if not

than three tons of overburden must be removed for ton of coal mined.

. 1 shows the method of stripping the Mammoth bed near ton, Pennsylvania. The coal is here about 60 feet thick itches about 40°. It originally outcropped at the sur-nd where stripping was begun only a small amount of e refuse had to be removed before the coal was ed. Owing to the dip of the coal, the overburden nes thicker quite rapidly; at the left of the illustration it wn about 20 feet thick. The method of operation is to ve the surface soil and any loose overlying rock with a shovel and then to mine out the coal with pick and l, aided by an occasional blast. The loosened coal is led by hand, or with a steam shovel, into cars, which isted up a plane. The work is usually carried on in sev-enches at the same time. The coal from the bench *a* is d up the plane *b*, while that from the bottom of the pit sted up a plane on the other side, the bottom of which is seen at *c*. Work on the bench *a* is represented as tinued, as is shown by the track *b* being partly up.

Bituminous-Coal Strippings.—Extensive stripping lso been done in some of the river bottoms of the

FIG. 2

rn Interior Coal Field where the formations are like shown in Fig. 2. The overburden is removed by shovels of the ordinary type, by special machines

similar to that shown in Fig. 2, or in some cases by hydraulic power where water is available or where there is a fall to carry off the water. Below the loose surface material *a*, a layer of slate or shale *b* several feet in thickness is usually found directly overlying the coal; this must frequently be drilled and blasted before it can be removed. As soon as the coal face has been opened up, a track *c* is laid along the face, and the coal as it is loosened from the face is loaded with the shovel directly into railroad cars running on a track as shown. In some cases the railroad cars cannot be taken to the coal face and the coal is then loaded into small cars, which must be subsequently hoisted up an inclined plane as was shown in Fig. 1 and then dumped into railroad cars. As the coal face is advanced, the tracks are moved close up to the face so that there is a minimum handling of the coal.

The excavator shown in Fig. 2 is a modified form of dipper dredge. The method of operating these excavators is to dig a channel, or dry canal, along one boundary of the area to be stripped. A track is then laid in this channel and successive strips of overburden are removed, exposing the surface of the coal, which is then taken out and loaded into railroad cars. These excavators usually work in pairs—the first removing the overburden to a depth of 20 feet, while the second excavator loads the coal from a section of the same width. After the first cut has been made, the waste material is placed in the excavation made by taking out the coal, and on the opposite side of the track *c* from the coal face.

5. **Disposal of the Overburden.**—The disposal of the overburden in stripping is usually an important consideration and as its thickness increases the difficulty becomes greater. If the overburden has to be transported to any great distance, the expense of this transportation may preclude the use of the stripping method. The presence in the cover of much water or sand greatly increases the cost of stripping, and as many of the deposits available for stripping lie in river bottoms, which are subject to overflow, there is often considerable

expense and difficulty encountered owing to the flooding of the strippings. In such cases, a dam or embankment is frequently built along the river bank with the material taken from above the coal beds, as shown at *e*, Fig. 2.

6. Comparison of Stripping and Mining Under Cover.—The **advantages** of stripping over underground work are that no timber is required, the men work in pure air and can therefore accomplish more, there is no danger from firedamp, mine fires, falls of roof and sides, no timbering and much better supervision of the work is possible. There is no cost for ventilating machinery, and if any hoisting is necessary only the simplest kind of machinery is required. Moreover, a larger working face is usually obtainable and in this way the output can be increased as desired.

The **disadvantages** of stripping are that the work is greatly retarded or completely stopped in stormy or very cold weather, while the disposal of the overburden is frequently a serious problem. By combining stripping with underground development, a mean cost of working may be obtained, which is considerably less than by ordinary underground methods, and the underground work can be laid out to better advantage, as the immediate demand for coal is supplied from the strippings.

ROOM-AND-PILLAR METHOD

7. General Description.—The **room-and-pillar method** is the oldest of the methods of mining, and is the one generally used in the mines of the United States. As shown in Fig. 3, the total coal area is divided into small districts, or blocks, by *main entries*, *gangways*, or *passageways a* and *cross-entries b;* the coal in each block is mined by turning off from the side entries a number of comparatively small places *c* called *rooms*, *chambers*, *stalls*, or *breasts*. A portion of the coal is left as pillars *d* to support the roof and overlying strata, *cross-cuts*, or *break-throughs*, *e* being made through the pillars at certain intervals so as to connect the rooms and

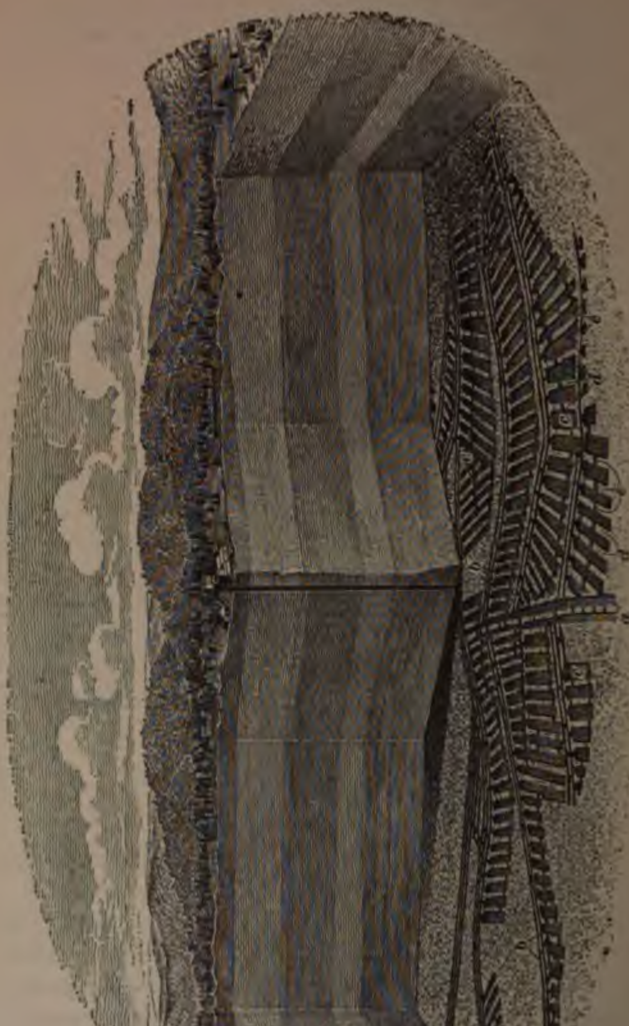


FIG. 8

as secure better ventilation at the working face. The moval of the coal in driving the entries and rooms is called e *first working* or *first winning* of the coal.

Unless it is necessary to leave in the pillars in order to event the surface above the workings from sinking, these lars are usually removed after the rooms have been driven full length; and unless the pillars can be removed the om-and-pillar method of working is very wasteful of coal, from 30 to 50 per cent. of the total amount of coal must left in the pillars by the first working. The removal of pillars is known as *second working*, *robbing*, *drawing back pillars*, *pillar working*, or *pillar drawing*.

In the mine plan shown in Fig. 3, the entries and rooms very irregularly laid out; but whenever possible the e entries *b* are driven at right angles to the main entries *a* d at regular intervals along the main entries. The oms should also, in a flat seam, be driven parallel to ch other and not irregularly, as shown.

ROOMS

8. **Definitions.**—The **face** of a room is the end where coal is being mined. The face is sometimes called the *east* of the room.

Inby is toward the face of the workings and away from e entrance.

Outby is toward the entrance and away from the face.

The **rib** is the coal along the side of a room entry or her opening.

9. **Turning Off the Room.**—A room *a*, Fig. 4, is not ually turned off the entry *b* full width, as it is necessary to ave an entry pillar *c*, sometimes called a **stump**, between e room and entry to protect the entry. The connection *d* etween the widened room and the entry is the **neck**, or **mouth**, of the room, which is ordinarily the same width as he entry—6 to 10 feet wide and from 9 to 30 feet long—epending on the roof pressure; the length of the neck is the istance from the entry to the point at which the room begins

to widen out. If the rooms are inclined to the entry, the necks must be longer than when they are at right angles to

FIG. 4

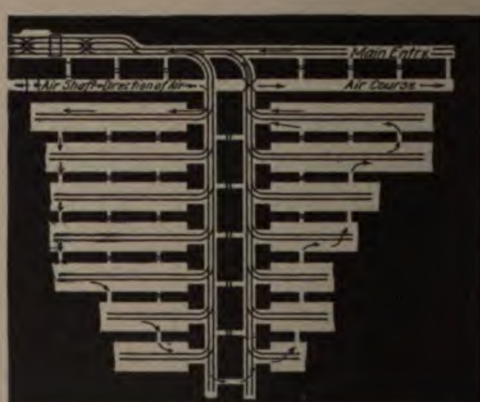


FIG. 5

the entry to furnish a substantial and proper-sized entry pillar. Room necks should be carefully driven so as not to break the entry rib or the roof unnecessarily. They should

preferably be mined by hand or machine and the ribs sheared, but they are often blasted off the solid. As the miner is usually paid yardage or given an extra allowance for driving such narrow places, he can afford to do this work more carefully.

The mine foreman usually marks off on the rib of the entry the position of the mouth of each room before the work of turning begins. Care should be taken in placing the first shots not to unnecessarily break the rib outside the marks given for the room neck. It is not possible to avoid this in all coal, but a bad practice prevails among a large number of miners of placing a shot on the rib line and breaking the coal equally on both sides, thus making the mouth of the room unnecessarily wide. In bituminous coal the rib should be sheared at the inby mark to a depth of 2 feet or 30 inches, and a grip shot hole may then be drilled from a point somewhat outside the outby mark, thus cutting off the sharp corner to provide a better clearance for the switch. After the first shot has been fired on the outby rib, this rib should be sheared on the line given by the mine foreman and the neck is then driven the same as an entry.

10. **Widening Out the Room.**—After the room neck has been completed, the room is widened out on one side, as shown in Fig. 4, or on both sides, as shown in Fig. 5. The rooms may be gradually widened out along an inclined line, as shown in Fig. 4, or along a line parallel to the entry, as shown in Fig. 5. The former is the preferable method, as the process of widening is more easily carried out in this way. A very common form of widening a room is that shown in Fig. 4, in which the outby rib is continued straight up to the face, while the room is widened out on its inby side. The shorter rooms on a mine plan are the last that have been turned and they therefore usually indicate the inby of the mine.

11. **Position of Track.**—It is usually customary to lay the track along the straight rib, as shown in Fig. 4, when the room is widened out on one side only, although in some

cases the track is laid up the center of the room, as shown in Fig. 5, in order to reduce the distance it is necessary to handle the coal at the face. The roof is supported over the track and at the working face by props. The rock and other waste material is usually stored in the space at the side of the track. It is of advantage to allow the roof to fall or settle on the waste, or *gob*, as it is called, in these vacant spaces in the rooms so long as the falls do not interfere with the roadway, since a fall of the roof relieves the weight on the pillars.

12. Width of Rooms.—Rooms should be turned off the entry at definite distances apart, the distance between room centers and the width of the room depending on the character of the roof, the coal and the bottom, the thickness of the coal, and the amount of cover above the coal. A rule for the widths of room and pillar applicable to all mines cannot be given, as each particular coal bed and each coal field has certain room-and-pillar widths that have been found to best meet its peculiar conditions.

The distances between the centers vary from 33 feet to 80 feet under different conditions. With 40-foot centers, the pillars are usually 12 to 16 feet wide, and the rooms 28 to 24 feet wide. When the centers are farther apart than 40 feet, the pillars are often 20 to 30 feet wide.

Narrow rooms, about 12 feet wide, are often driven and wide pillars of 60 to 70 feet left between. The greater part of the coal is then got out by drawing back these wide pillars, as explained later.

When the room centers are 40 feet or more apart, if the coal is soft the pillars are wide and the rooms narrow, but if the coal is hard the rooms are wide and the pillars narrow, provided that the roof and floor conditions will permit.

The ratio between the width of the room and width of pillar in general decreases with an increase in depth below the surface.

When an undue proportion of coal is mined in the first working, creeps are brought on, with all the accompanying

evils of crushed coal, dilapidation of roadways and airways, extra cost for labor and material in repairing damages, and diminished production.

13. Length of Rooms.—The length of the rooms is governed by the distance decided on between entries. It is usual to make them from 150 to 300 feet long, the former being preferable in thin beds and the latter in thick and steep pitching beds in order to avoid the expense of narrow work and cross-entry rails. The length of the rooms is also somewhat governed by the distance to which the coal can be economically hauled from the face to the entry, and by the gas present in the coal.

14. Break-throughs, or **cross-cuts,** are passages made in the pillars between rooms or between entries for purposes of ventilation. Frequently, only every alternate room pillar is cut through, the rooms being thus connected in pairs and each alternate room pillar being left whole. In the event of fire in any room with such an arrangement, it is only necessary to build stoppings at the mouths of two rooms instead of closing off the whole district. As the mine is developed, it will be necessary to abandon such a practice in order to assist the ventilation of the mine by shortening the distance the air must travel.

The distance apart of break-throughs depends on the amount of gas given off by the coal, on local practice, and on the mine laws of the state or country; for instance, the Bituminous Mine Law of Pennsylvania makes the minimum distance between break-throughs 16 yards and the maximum 35 yards.

Rooms driven to the rise are more difficult to ventilate than flat rooms or rooms driven to the dip, owing to the tendency of the air heated by the lamps and presence of the workmen to remain at the face; on this account, break-throughs are made at shorter intervals than in flat seams. Rooms driven to the dip are more easily ventilated than flat rooms or rooms to the rise, and the distance between break-throughs may be increased.

The size of the break-through should be such that the air-current will not be restricted; and as a general rule they should have the same cross-section as the airways, but this is not always carried out, especially in extensive workings where the quantity of air in circulation is barely sufficient for the ventilation of the mine. In small mines and in the early development of large mines, the size of break-throughs is not so important a matter.

To insure proper break-throughs, they should be driven and paid for as narrow work; this is the custom in most mining districts. The miners are often required to turn break-throughs at regular intervals and at right angles to the rooms, the break-throughs in the adjoining rooms being opposite to each other; the miners in each room work half way through the pillar and are met by the miners driving from the adjacent rooms. If the break-throughs in adjoining pillars are driven in line, they can be utilized for roadways, or for drainage purposes if necessity requires. They should be measured off and driven with the same care as rooms and have their sides faced up with the same care as entries.

The rooms should not be widened out and corners rounded off at break-throughs, although in many cases the expense of driving break-throughs is avoided by allowing the miners to gradually increase the width of the room until they hole through the pillar separating the rooms. The miners then fall back to the proper width of room and continue at this width until near the location of the next break-through when the room is again gradually widened. This is poor mining, for, though it avoids the expense of yardage for break-throughs, it weakens the pillars, and the opening between the rooms is generally too small for the required air-current and the face is usually irregular. To avoid this widening of the room, frequent measurements should be made at the face to see that the miner is not increasing the width of the rooms.

15. Room Sights.—The rooms are kept in line by means of sights driven in the roof and located from the

entry. These sights may be plugs of wood with a nail driven into them from which a plumb-bob may be suspended, and should be made different from the survey stations so that the two may not be confused. The last sight in place in the room should not be more than 10 or 12 yards from the face. Plumb-bobs are hung from the nails and a sight taken to the face by lining in the two plumb-bob strings until they appear as one. A very convenient method is to place these plugs over the center of the track in the room, as it is then easy to keep the ribs straight by measurement from the track. The line of sight up the room and from which the measurements to the rib are taken is often called the room center, although it may be at one side near the rib; the *distance between centers* of rooms means the distance between these sight lines. The ribs should be measured and dressed after each round of shots that takes off a slice of coal across the face.

SPECIAL METHODS OF OPENING ROOMS OFF ENTRIES

16. Double Rooms.—Rooms with a single neck, as illustrated in Figs. 4 and 5, are called **single rooms.** In working some coal beds, it is necessary to have a greater length of face in each room than is afforded in a single room; to accomplish this, **double rooms** are driven, as shown in Fig. 6. A double room is one having two openings and generally two straight ribs, with a track laid along each rib. The waste is stored between the tracks, and, where there is plenty, pack walls are built along the track so as to form two roadways leading to the face. With this form of room, as will be observed in the figure, the pillars are generally wider than in single-room work, and the distance the coal has to be handled to the track is practically the same both in the first and second workings.

FIG. 6

17. For the purposes of ventilation in gaseous seams, or as a protection against squeeze, to which a bed of coal may be especially liable, or for the purpose of starting a long face for machine working, rooms are sometimes turned off of an entry as already described, but are opened into each other by the removal of the pillar in the first working, thus forming a continuous breast, as shown in Fig. 7.

FIG. 7

18. Extra Entry Pillars.—Where there is excessive weight on the entry pillars, it is necessary, in order to keep open the entries, that these pillars be very large, or that a special pillar be left to protect the entry used as a haulage road, while the rooms are opened out from a parallel entry or cross-cut.

Fig. 8 shows a method used at Danville, Illinois, where the coal is underlaid by a soft bottom, but has a strong cover. The weight of the cover would tend to force the pillars into the bottom and thus close up the entries. This is prevented by leaving the extra pillar. The main entries *a* are driven and timbered for a double track; the cross-entries *b* are driven 10 feet wide and the first room neck *c* is turned 10 feet wide and driven up 15 feet and then widened out on one side to a full width of 30 feet. A cross-cut *d* is driven 20 feet wide and two more rooms are turned off this cross cut, as shown; the fourth room is turned directly off the cross-entry, widened out on the right, and a cross-cut turned to the right as before and two more rooms are turned off this cross-cut, etc. The large entry coal pillars *e*, 40 feet by 125 feet in size, keep the weight off the cross-entries; and by making a rather thin pillar between the rooms, the weight is thrown on the face and made to

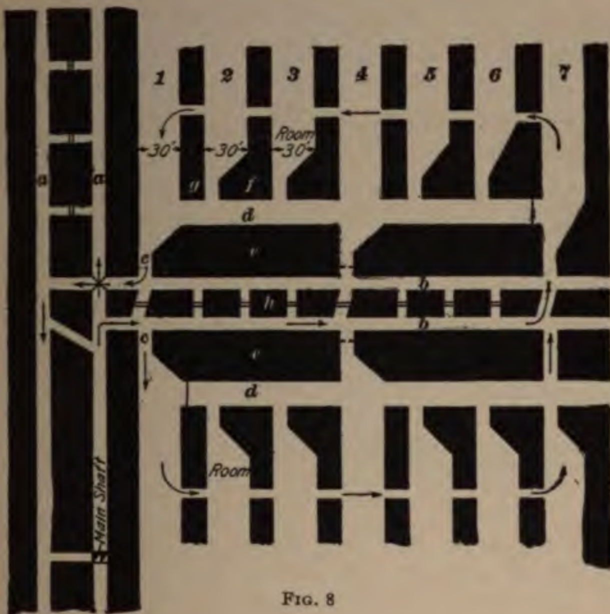


FIG. 8

FIG. 9

assist in the mining. In the second working, these large pillars can be taken out, as well as the stumps *f*, the room pillars *g*, and the pillars *h* between the entries.

19. Fig. 9 shows another method of turning off the rooms in order to give additional support to the entries. Large pillars *a* are left above the entry *b*, and from each neck *c* turned off the entry *b* two roads *d* are driven, one along each side of the room pillars *e*. This plan has been successfully used in a bed of hard coal with a strong bottom and a thick, strong roof.

DIRECTION OF DRIVING ROOMS

20. The direction in which rooms are driven with respect to the entries off which they are turned depends on the inclination of the bed, the cleat of the coal, and the nature of the overlying rock. When possible, the rooms are usually driven at a right angle to the entry. If the bed is flat, the rooms may be turned both to the right and to the left of the cross-entries, and in such a seam, and where the entries are driven in pairs, a series of rooms is often driven off each entry of the pair. If the bed is inclined to any extent, the rooms are turned only to the rise of the higher entry, the other entry of the pair being used as an air-course. Rooms are usually not turned to the dip if much water will accumulate at the face. Where there is not much water to collect at the face, the rooms may be turned to the dip on a pitch as high as 6°, although, if the loaded car must be hauled out by a mule, the dip of the room toward the face should preferably not exceed 3° to 4°. If the loaded cars are pushed out of the rooms by hand, the road should dip from the face toward the entry, or should at least be level. A car can be controlled by spragging when pushed by hand until the inclination of the track is about 6°; that is, until the grade is about 10 per cent.

21. Rooms Inclined to the Entry.—As it is not usually practicable to haul empty cars up a grade of more than 6° to 8°, if the pitch of the bed is greater than this but less than about 12°, a suitable grade for haulage may be-

secured in the rooms by driving the rooms at an angle to the entry, as shown in Fig. 10. The method of working an inclined room does not differ from that used where the room is at right angles to the entry. The angle that the room makes with the entry should not be less than 30° or the entry pillar will not have the required strength, unless it is left very large. Where rooms are driven at an angle to the entry, as shown in Fig. 10, the coal between the first room and the slope or main entry, as the case may be, is worked out by means of cross-rooms *b* driven off from the first room *a* as shown. When the inclination of the bed is above 10° to 12°, the rooms are usually turned at right angles to the entry and the coal conveyed from the face to the entry and there emptied into the mine car.

Fig. 10

Rooms driven to the dip are also sometimes driven at an angle to the entry where the inclination of the seam exceeds 3° and where mule haulage is used in the rooms.

22. The angle that a room should make with the entry in order to obtain a given grade of track in a seam having a given inclination is calculated by the following rule.

Rule.—*The sine of the required angle between the room and the entry is equal to the quotient obtained by dividing the tangent of the grade angle by the tangent of the dip angle or angle of inclination of the seam.*

Expressed as a formula, this rule is,

$$\sin C = \frac{\tan B}{\tan A}$$

in which A = dip angle or angle of inclination of seam;
B = grade of roadway, in degrees;
C = horizontal angle between room and entry.

Any of the three angles may be calculated from the formula when the other two are given.

EXAMPLE 1.—What should be the angle between the room and gangway in a seam pitching 6° 10′, in order to give a grade of 3° on the roadway?

SOLUTION.—In this case, $A = 6° 10'$ and the tangent of 6° 10′ is .10805. $B = 3°$ and the tangent of 3° is .05241.

$$\sin C = \frac{.05241}{.10805} = .487; \text{ and } C = 29° 9'. \quad \text{Ans.}$$

EXAMPLE 2.—Calculate the grade of a road in a room making an angle of 45° with the entry, when the inclination of the seam is 10°.

SOLUTION.—In this case, $\tan B = \sin C \times \tan A = \sin 45° \times \tan 10°$. Sin 45° = .707, and tan 10° = .1763; substituting these values in the formula,

$$\tan B = .707 \times .1763 = .12464+; \text{ and } B = 7° 6'. \quad \text{Ans.}$$

Expressed as percentage, the grade of this road is 12.46 per cent.; or the road rises 12.46 feet in each 100 feet of horizontal distance.

23. Direction Determined by Cleat.—As described in *Geology of Coal*, many coal beds have more or less pronounced *cleats*, *joints*, and *bedding planes*. The **face cleats** are the longer and usually the more pronounced, while the **end cleats** are the shorter and more irregular ones. Coal sometimes breaks more easily on the face cleats and sometimes more easily on the end cleats. Hence, the cleat of the coal often determines the direction in which the room should be driven, since there is one direction in which the coal breaks best, producing a larger amount of coal for a given amount of undercutting. The cleats and bedding planes should also be considered when blasting coal to produce the greatest effect by the blast. There are five ways of driving with respect to the cleat, known as *face on*, *long horn*, *half horn*, *short horn*, and *end on*.

FIG. 11

24. In driving **face on,** Fig. 11, the opening is driven so that the face is parallel to the face cleats, which are represented by the long white lines, while the end cleats are shown by the

shorter white lines. This is the general method of driving rooms and is adopted where conditions permit. Face on is adopted where the face cleats are not as free or as numerous as the end cleats. Coal worked face on breaks well, and the yield is perhaps larger for the same amount of undercutting and shearing than by any of the other methods, producing also a greater proportion of large coal.

25. In driving **long horn,** Fig. 12, the opening is driven so that the face makes an angle less than 45° with the face cleats of the coal; the coal breaks in long slabs or wedged-shaped masses, giving rise to the name long horn. A face driven long horn does not require the same amount of cutting; and if slightly inclined grip shots are used, this method yields good-sized lumps of coal. If the coal works too freely face on, by this method, support is given the ends of the coal while being undercut.

FIG. 12

26. In driving **half on,** the openings are driven at an angle of 45° with the cleats of the coal. The method is adapted to coals that break about equally well on the face and the end cleats.

FIG. 13

27. In driving **short horn,** Fig. 13, the face of the opening makes an angle between 45° and 0° with the face cleats. It is adapted to the working of coal where the end cleats are so pronounced as to require the additional support given to the coal by this method when mining or under-cutting. The method bears the same relation to end-on work that long horn bears to face on.

28. In driving **end on,** Fig. 14, the openings are driven parallel to the face cleats, making the working face parallel to the end cleats. This method, and that last described, are adapted to the working of coals under strong roof pressure. In general, the size of the coal and the yield are not as great as in face-on or long-horn openings. As the face cleats are quite pronounced when openings are driven end on, wide pillars are generally used.

FIG. 14

When there is much occluded gas at high pressure, the direction of the working face with respect to the face cleats of the coal is important, since a breast driven face on, affords little or no opportunity for the escape of this gas, except as it finds vent in violent outbursts. On the other hand, if this coal be worked end on, the face cleats are cut across and exposed and the gas escapes gradually and quietly. The method by short horn or half on, may be found to give good results in such a case, since the pressure of the gas is then made to do effective work in assisting to break down the coal.

29. Direction Determined by Slips in the Roof. A roof slip, represented by the diagonal lines in the roof in Fig. 15, is a line of weakness that was at some time a line of fracture in the rock and which may or may not have been filled subsequently by infiltration with clay or other matter. Roof slips frequently occur in parallel lines in the rocks overlying coal seams; if this is the case, there is great danger from roof falls if the room face is parallel to the direction of the slips,

FIG. 15

for the miner cannot see the slip until too late to prevent accident by the falling of the slate or the sudden breaking down of the coal. By driving the room at an angle across the slips, not only is sufficient support given to the roof to prevent its breaking suddenly, but the presence of the slip is readily observed.

When the face is at right angles to the direction of the slips, there is not the same danger at the face as when the face is parallel to the slip, since the roof is better supported by the coal. The chief danger occurs when drawing back the pillars, for as the slips are parallel to the line of the pillars, a large fall may occur suddenly at any time by an unexpected cross-break. In any case, when driving under such roof, a larger amount of good timber is required.

DRAWING PILLARS

30. Order of Drawing.—The work of **drawing back, or robbing,** that is, removing the pillars left in the first working, should be commenced as soon as the rooms are worked up their full length, whenever this is possible. If this is delayed, and the openings left to stand for any length of time, the roof will settle heavily on the pillars and there will be danger of crushing them and thus losing the coal. Fig. 16 illustrates the way of drawing the pillars in rooms turned off one side of a single pair of entries where the drawing begins next to the main entries and progresses inby.

The drawing of the pillars has been completed in rooms *1*, *2*, *3*, and *4*, down to the entry pillars *a*, which are left and these rooms are closed; the work on pillars *5*, *6*, and *7* is in progress; rooms *8* and *9* have reached the limit, and the work on the pillar separating rooms *8* and *9* will now begin. The rooms inside of number *9* have not been completed, and the last room on this pair of entries has just been turned. After the cross-entries *b* and *c* have been completed and all of the rooms off them completed and the pillars between the rooms drawn, the pillars between the entries *b* and *c* and the stumps *a* will be drawn back to the main entries *d*. It is

advantageous to carry on the pillar drawing systematically and to keep the ends of the pillars in a line to avoid excessive pressure being brought on a single pillar by the drawing of the pillars on either side of it. Unless the ends of the pillars are kept in line, there is also increased danger from

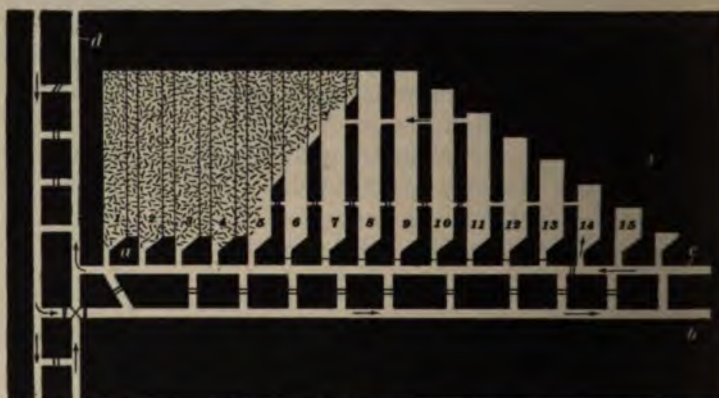


Fig. 16

falls, and the work of drawing timber is made more difficult. If rooms are driven toward each other from adjoining cross-entries, a pillar should be left between the ends of the rooms and removed when the pillars between the rooms are taken out.

31. Fig. 17 shows the reverse method of drawing the ribs, that is, from the inby end of the entries or headings toward the haulage roads. The cross-headings *a* are driven in pairs off the main headings, and off of one of these cross-headings other headings *b*, called butt headings, are driven. These butt headings divide the mine into panels and they are driven their full length, but so as to leave a chain pillar *c* between the end of the butt headings and the next pair of cross-headings. The rooms are then started from the inby end of the butt headings, and as soon as the first or inby room has been driven up to its full length, leaving a chain pillar between it and the next pair of butt headings, the

pillars are drawn, as shown at *d*. As soon as the pillars have been drawn back to the butt headings, the pillars *e* between the butt headings, and the chain pillar *f* between the lower butt heading and the next lower tier of rooms are drawn back as shown. The advantage of this method over that illustrated in Fig. 15 is that both the room and pillars

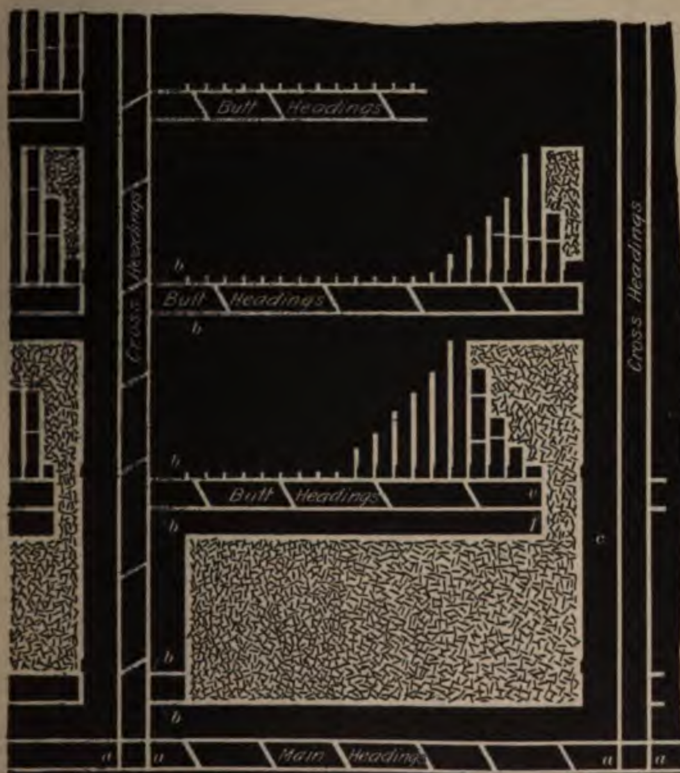


Fig. 17

and the entry pillars are drawn back in one operation, instead of the room pillars being first drawn and the entry pillars and stumps drawn subsequently. A greater portion of the total amount of coal is probably obtained in this manner when it is possible to carry it out.

32. The method of drawing back the pillars illustrated in Fig. 18 is similar to that shown in Fig. 17, but it is extended over a much larger area. The cross-headings *a* are driven to

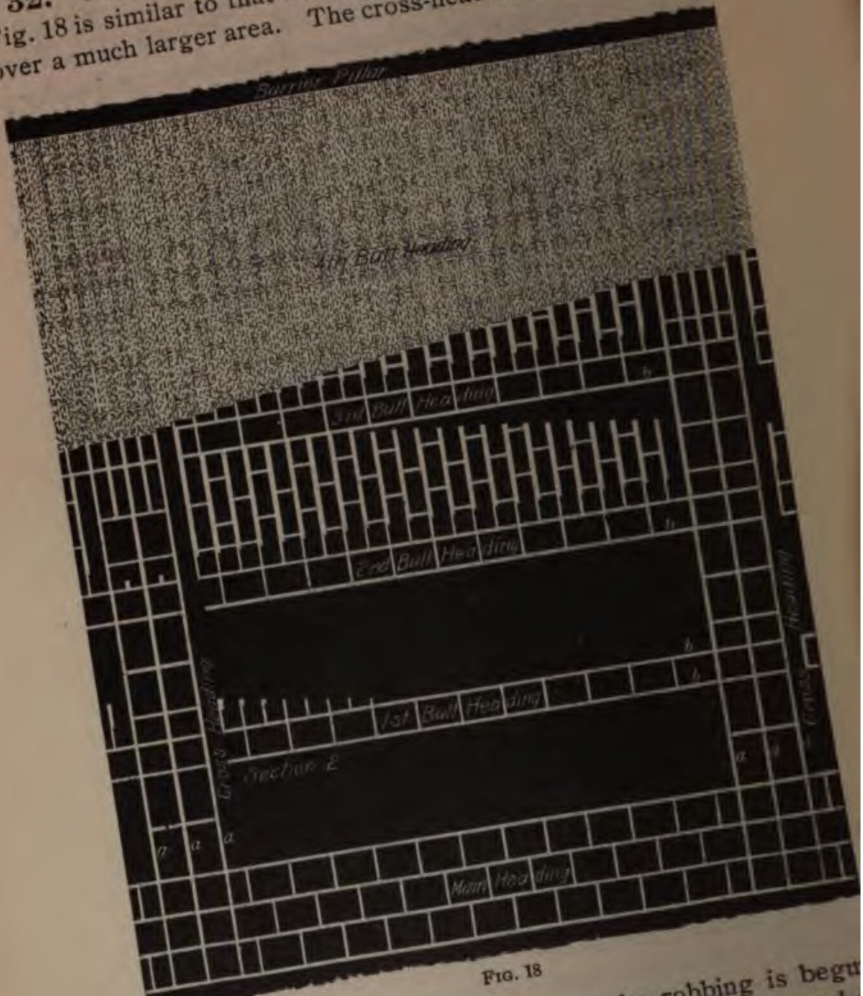


FIG. 18

the boundary of the property before the robbing is begu
from these headings the butt headings *b* are driven, and
these, narrow rooms, as shown. The pillars over the ent
length of the property are then brought back at one time.

33. Work of Drawing.—When the work of drawing the pillar is to begin, a cut through is driven from the face of each room to the face of the room adjoining so as to give a free face across the end of the pillar. There are a number of ways of attacking the pillar, the choice of a method being determined by local conditions and custom.

Fig. 19 illustrates one way of drawing back pillars separating wide rooms in which there is a track along each rib of the pillar. The work of drawing back the pillars is shown as having just begun, the pillars having been cut through at the face, and the first shots having removed the coal at each corner of the pillar. The second holes *a* will remove the

FIG. 19

remainder of the first slice across the pillar and the holes *b* the first cut of the second slice. The coal is thus removed in steps. A row of props *c* keeps up the roof along the face of the pillar. As the pillar is drawn back a sufficient distance, a second row of props similar to that shown at *c* is stood across the face of the pillar, parallel to the first row *c*, which is then withdrawn. In pillar drawing, the back timber should be drawn only so fast as to throw a proper weight on the pillar. If this weight is excessive, the end of the pillar is crushed. An excessive weight is also thrown on the pillars by leaving too much timber standing. Just how much timber to use can be determined only by experience. If the pillar is very wide, a slice or skip may be taken off it from the entry to the face before the pillar is cut across at the face.

When the pillars have been drawn back to the entry stub at the mouth of the room, where the room begins to narrow toward the neck, care should be taken to break the roof, if necessary, back to the entry pillar or stub. With a hard roof, it may be necessary to place one or two shots in the roof at this point. By this means the entry pillars are relieved of excessive pressure due to the settlement in the abandoned rooms, which have been closed by the drawing of the pillars.

34. Fig. 20 shows other methods very commonly used for drawing pillars in both flat and inclined seams, known as *splitting a pillar*. In the method shown in Fig. 20 (*a*), the opening *b* is driven up the center of the pillar as wide as the strength of the roof will permit without crushing the pillars left between this opening and the rooms. Each of these small side pillars is then drawn back in slices by a method similar to that shown in Fig. 19. In Fig. 20 (*b*), the pillar is shown divided into a number of small pillars by cross-cuts *c*. Each of these small pillars is then divided lengthwise as shown at *d*. In Fig. 20 (*c*), the pillar is divided up its full length by a narrow place *e*. This narrow place and the break-throughs *f* divide the original pillars into a number of small pillars *g*. These small pillars are next broken up by other cross-cuts *h*, leaving still smaller pillars, and these are then taken out by shots, as shown.

FIG. 20

35. Delayed Pillar Drawing.—The work of drawing pillars between the rooms is sometimes preferably delayed until the entries have been driven to the boundary and the rooms also worked up to that point, when the work of drawing pillars will be commenced at the boundary and proceed uniformly toward the mine opening. This may be necessary in the working of two beds separated by only a few feet of

solid strata where a number of overlying beds are worked; or in certain cases where the bed is overlaid by water-bearing strata, and where the breaking of the roof rock would result in the flooding of the mine.

When this method is used, a constantly increasing extent of airways and roadways must be kept open and in repair, until the robbing begins, while the difficulties of ventilation are also increased. Again, the pillars first formed are last removed and there may be a loss from depreciation of the pillar coal due to weathering and also from the crushing of the pillars, unless much larger pillars are left than are required when the pillars are drawn as soon as the rooms are finished. With fairly thick and very soft coals, the rapid working up of the rooms and equally quick drawing of the ribs as soon as the rooms are driven their full distance, is essential to economical working; for delay in extracting ribs and pillars in such circumstances results in their getting crushed and the coal lost or largely ground to slack.

36. Precautions in Pillar Drawing.—When two or more overlying seams are worked simultaneously, the pillars in the lower seam should not be removed until the upper seams have been worked out and the pillars removed.

It is not generally advisable to attempt to draw the pillars in a limited area surrounded by a district in which the pillars are not drawn, particularly under a hard roof, as an excessive weight will then be thrown on the pillars left standing and a disturbance set up that may extend a long distance from the immediate district from which the pillars are removed.

In very gaseous mines, the pillars are sometimes not taken out until the workings have reached a considerable distance from the shaft, in order that there may not be accumulations of gas in the gob and waste near the shaft, since it is often more difficult to prevent gas accumulations in robbed workings than when the pillars are left standing. If the coal is tender, the removal of the pillars should be delayed if the roof will not fall readily, because if they are taken out,

excessive pressure may be brought on the entry pillars. In the case of bad roof, the pillars should be taken out as soon as possible, not only for economy, but also because, when the roof is bad and falls freely as the pillars are drawn, the débris soon sustains the superincumbent pressure and relieves the weight on the pillars next to the entries. Early drawing of pillars also concentrates the working district, and, excepting in a gaseous mine, reduces the area to be ventilated.

With a strong roof that does not break readily when the pillars are removed, great care must be taken that the removal of the room pillars does not bring sufficient weight on the entry pillars to crush them. A weak roof falls freely and soon fills up the gobs, thus partly sustaining the pressure from the roof and relieving somewhat the weight on the pillars along the side and main roads, due to the layers of rock immediately above the coal.

If the roof has fallen in the rooms before the work of drawing begins, the strata above the pillar can usually be kept up comparatively easily by props about the working face, without great danger to the miner, but where the roof remains over the rooms, excessive pressure is often thereby thrown on the pillars and the work of drawing is very dangerous and treacherous; under such circumstances, the whole pillar can rarely be removed, as it will usually crush before it can be taken out.

In drawing pillars, their ends should be kept in a straight line, for if they are not, some pillars are subjected to greater pressure than others, valuable coal is lost, and the work is materially interfered with.

Especial attention should be paid to the effect of the removal of the pillars on the surface and the overlying strata, particularly if the latter are water-bearing or contain running materials, such as quicksand.

The work of drawing pillars is particularly dangerous where faults or slips are frequent in the roof, or top coal is to be taken down, or where pot bottoms, sink holes, boulders, etc. are of frequent occurrence in the roof, or where the

workings underlie or approach buried valleys or extensive beds of quicksand.

Where the pillars are crushed and creviced, blown-out shots are liable to occur in their working. Undermining, in pillar work, should be done with caution. Pillar coal can sometimes be undermined with machines, but the practice is not general and hand work is usually depended on. Small stumps, or portions of pillars should not be left scattered through the gob, as they interfere with the uniform breaking of the top.

The conditions at different mines are so varied that no general rule can be laid down to suit all. There is probably no more dangerous work in mining than pillar drawing and the method adopted depends largely on local conditions and on the experience of the miner.

Pillar drawing in inclined seams will be treated later in as far as it differs from that in flat seams.

SIZE OF PILLARS

37. Amount of Pillar Coal.—The amount of coal left in the pillars for the support of the workings is generally expressed as a percentage, or a certain portion, of the total volume of the bed within the area included by the pillars. The term **pillar coal**, therefore, includes not only the coal left in the room pillars, but also that left in the pillars supporting the entries. The amount of coal left in the pillars in the first working varies widely under different conditions, but the best practice now counts on ample pillars in the first workings so as to minimize the danger from squeezes. Many of the collieries in the anthracite region of Pennsylvania are now extracting but one-third of the coal in the first working, leaving two-thirds of all the coal as pillars to be taken out later as the different sections of the mine are worked up to the limit. In many of the mines in the Connellsville region of Western Pennsylvania, the rooms are only 12 feet wide and the pillars from 60 to 72 feet wide, so that only one-fifth to one-sixth of the coal is taken out in the first working, but the removal of

the pillars begins as soon as the rooms have been driven their full length.

The proportion of coal left in the pillars along the entries to the amount of coal taken out in mining the entries is relatively larger than the percentage of pillar coal between the rooms, as the entry pillars usually have to stand a much longer time than the room pillars.

The amount of pillar coal left depends on the method of working the mine, on the nature of the coal, the top and the bottom, on the thickness of the coal, and the depth of cover, and on the time of drawing the pillars.

38. Practical Considerations Determining Size of Pillars.—It is impossible to give exact rules or formulas for determining proper size of pillars and rooms that will be universal in their application. Each mine is a special problem, and in laying out the rooms and pillars it is well to find out what is the successful practice in the same field or in similar fields worked under the same conditions. Similar practice should not be followed blindly, as a great deal of the lack of progress in mining methods has been due to this copying of other methods. Still it is always well to find out how others have succeeded and why they have failed. Because a certain system has worked successfully in one region is no indication that it will work successfully where the conditions are different.

In general, the thicker the bed and the greater its depth below the surface, the wider must be the pillars and the less the opening; this rule is, however, not invariable, for certain coals deteriorate very rapidly when exposed to the atmosphere, and in such coals the pillars must be much larger than with hard compact coals under similar conditions.

The length of time that a pillar must stand before it is to be drawn should be considered in determining the width of the pillar required. If a pillar is to be drawn in a short time, it need not be as large as one that is to be more permanent, as it is not subject to the disintegration due to pressure and to atmospheric effects.

Extremely large pillars are usually left to protect surface buildings, and also under swamps or large bodies of water to avoid any possibility of a break in the roof through which the water can enter the mine.

Some coals are of such a nature that the sides and corners of pillars chip or split off when the coal is opened up, due to the disintegrating effect of the atmosphere, to the pressure of gas in the coal, or to the pressure of the roof. When this chipping or splitting off of pillar coal occurs, pillars of greater area are required.

Strong heavy strata, such as limestone or sandstone above the coal, that do not break and fall easily, act as a lever to crush the edge of the coal pillar and require larger pillars to prevent creep and squeeze, than where the pressure is distributed over the pillar and not so much along the edge; under a friable roof, such as black shale or slate, that breaks and falls easily, and thus relieves the pressure on the edge of the pillar, a smaller pillar can often be used than under a strong compact roof, which brings the weight on the edge and constantly chips off the pillar. With a strong roof that does not break, there is danger from a movement of the strata over the pillar when robbing begins. A soft bottom requires a large pillar to prevent the heaving of the bottom. Faults, slips, and similar geological disturbances in the roof generally increase the size of the pillars, and also the difficulty and danger of drawing them.

If the floor is soft and the roof hard, a *creep* is likely to occur, and in such a case small pillars are so squeezed down into the floor as to be both troublesome and expensive to remove. If the floor is hard and the roof brittle, the latter will fall more or less in spite of all efforts, and the expense of "cleaning up" and timbering is heavy. If top and bottom are both strong, the weaker substance—the coal if left too long or in too small an amount—is crushed, and its value decreased or lost.

If the seam of coal is gaseous, the length of the pillar is decreased on account of the length of the cross-cuts or break-throughs required to ventilate the rooms, thus necessitating a wider pillar than would otherwise be required.

While it is desired to have a certain excess of strength in the mine pillars, the expense of driving long cross-cuts through the pillars, for the purpose of ventilating the openings, as well as the necessity for realizing as large a percentage as possible of coal in the first working, makes it desirable in many cases to use the minimum width of pillar required for the safe support of any given roof pressure.

The best results as regards the percentage of coal won from a coal bed are undoubtedly obtained where narrow rooms are driven in the first working with ample pillars left between, and when the pillars are withdrawn as quickly as possible after the rooms are worked up their full length.

When two or more beds are worked at the same time, the width of pillar required in the lowest bed will, in most cases, determine the maximum width for all the overlying beds, for the pillars should be placed with their center lines vertically one above the other, and if any difference is made in the size of pillars in overlying beds the lower of the pillars should be the larger. This is the more important the closer the seams are together.

39. The **inclination** of the seam, although decreasing the normal pressure or the pressure perpendicular to the roof and floor, gives rise to a tendency of the roof to slide on the pillars when the coal is removed. This tendency greatly increases when the work of drawing the pillars is begun, especially if the roof is hard and fails to break. Although the decreased pressure in an inclined seam would call for a narrower pillar than for a flat bed, the tendency of the roof to slip necessitates an increased width over what would be required in a flat bed with the other conditions similar.

40. Theoretical Consideration Determining Size of Pillars.—Although the size of the rooms and pillars must largely be determined by experience, there are certain general theoretical considerations that are helpful in laying out a mine. Whenever an opening is made in a coal bed, the roof above the opening must sustain the weight of the strata above or the roof will break and fall. The weight

of the overlying strata is transmitted from the roof to pillars of coal on each side of the opening, and this weight resting on the pillars is, in turn, transmitted to the floor under the pillars. The theory of room-and-pillar mining includes an investigation of the effect of taking out the coal from the rooms on the roof, pillars, and floor.

41. Roof Conditions.—Fig. 21 represents a case where the roof is a thick, homogeneous, tough rock, that does not break readily. The roof over a very considerable opening

FIG. 21

will therefore stand and will act as a beam transmitting the entire weight of the overlying rocks to the pillars.

Fig. 22 illustrates the case of a thinner and more flexible roof, which sags when the coal below it is removed, throwing

FIG. 22

increased weight on the edge of the pillar at *a*; finally, if the opening is too broad, the roof breaks.

Fig. 23 represents a case where the roof does not act at all as a beam to transmit pressure to the pillars and where the rock over the opening is fractured by the superincumbent weight. The height to which the breaking of the rock

extends depends largely on the character of the rock. A certain amount of the loose rock will fall into the openin unless supported by timbers; but much of this loose broke rock probably settles down and binds, forming over the opening an arch $a\,b\,c$ that is self-supporting. The height of this arch depends on the character of the rock. With a tough

FIG. 23

roof rock, a flat arch $a\,b\,c$, Fig. 23, will be formed, while in a loose fragile roof, the arch will be higher and the rock more cracked, as shown in Fig. 24.

The weight of the broken material forming the arch and of the overlying strata is carried by the arch to the pil

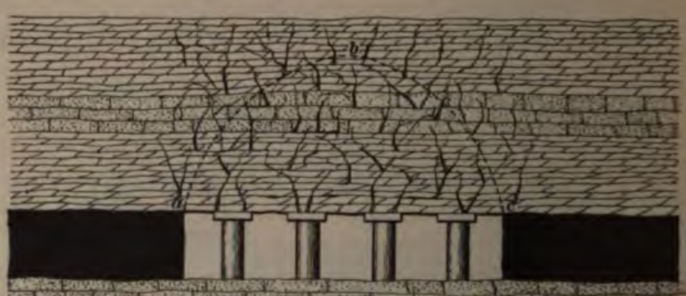


FIG. 24

lars on each side of the opening. The loosened material beneath the arch may be supported on mine timbers. This distinction should be clearly understood, for mine timbering cannot, as many seem to think, support the weight of all the superincumbent strata, but only all or a part of the weight of the portion under the arch, while the greater part

of the superincumbent weight comes on the pillars of coal. If the pillars are not to be crushed, their strength must be greater than the weight thrown on them.

42. Depth of Cover.—The cover of a seam is the overlying strata, and the **depth of cover** means the thickness of such overlying strata, or the depth of the seam below the surface. The **superincumbent weight** is the weight of cover resting on the seam. The average weight of the rocks of the coal measures is given in Table I.

TABLE I

Rock	Weight per Cubic Foot Pounds
Clay	115
Earth	100
Gravel	117
Limestone	165
Sand	117
Sand full of water	120
Sandstone	150
Shale	162
Slate	175

It is safe to assume an average value for the weight of the entire overlying strata of 160 pounds per cubic foot. The superincumbent weight W for each square foot of area, and for a depth of cover d is then,

$$W = 160\,d$$

This does not take account of the fact that owing to the spherical shape of the earth, the whole weight does not rest on the bed, but it is a sufficiently accurate assumption for all practical mining purposes.

EXAMPLE.—Find the weight, per square foot, resting on a bed 500 feet below the surface.

SOLUTION.—The depth of cover in this case is 500 feet, and substituting this value in the formula, the weight of cover per square foot of area is

$$W = 160 \times 500 = 80{,}000 \text{ lb.}$$

43. Load on Pillars.—Since the removal of the coal throws the total load on the pillars, the roof pressure per square foot on the pillars is increased in the ratio of the total area of the opening and pillars to the area of the pillars. In Fig. 25, o represents the width of an opening separated

from other similar openings by pillars, the width of each pillar being w. A weight of cover equal to $w + o$ then rests on each pillar w, and if L represents the roof pressure or load per square foot on each pillar,

FIG. 25

$$L = 160\, d\, \frac{w + o}{w}$$

EXAMPLE.—Find the roof pressure at a depth of 900 feet below the surface, when the rooms are driven on 70-foot centers with pillars 50 feet wide between them, the width of the rooms being 20 feet.

SOLUTION.—In this case, $d = 900$, $w + o = 70$, and $w = 50$. Substituting these values in the formula,

$$L = 160 \times 900 \times \tfrac{70}{50} = 201{,}600 \text{ lb. per sq. ft.}$$

$$\frac{201{,}600}{144} = 1{,}400 \text{ lb. per sq. in.}$$

$$\frac{201{,}600}{2{,}000} = 100.8 \text{ T. per sq. ft. Ans.}$$

This roof pressure must be below the safe crushing strength of the coal if the pillars are to stand.

44. Crushing Strength of Coal.—There is very little data on the crushing strength of coal, and the values given in Table II, based on experiments made under the auspices of the Engineers' Club of Scranton, Pennsylvania, on anthracite, are therefore of interest. These results are averages from a large number of tests made on anthracite from a number of different beds and from different parts of the anthracite field. The samples were right prisms having a uniform base 2 inches square, but three heights of prisms were tested as far as possible for each sample of coal. These heights were 1, 2, and 4 inches, respectively, as shown in Fig. 26.

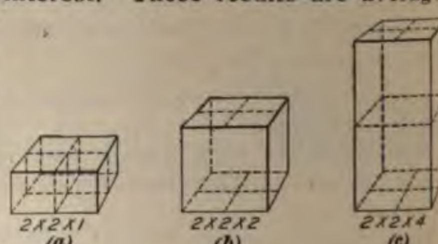


FIG. 26

These tests suggest the following conclusions in regard to the samples tested:

Although the area of the base or area pressed is the same in each case, the total crushing load and the crushing load per square inch are not the same in the different samples, but vary, approximately, inversely as the square root of the height of the sample; that is to say, sample (*c*) having four

TABLE II

AVERAGE COMPRESSIVE STRENGTH OF ANTHRACITE

	Sample (*a*) Pounds	Sample (*b*) Pounds	Sample (*c*) Pounds
Total crushing load	23,000	16,348.000	11,416.0
Crushing load per square inch	5,750	4,087.000	2,854.0
Load producing first crack in sample	3,022	2,025.000	1,875.0
Height h	1	2.000	4.0
$\sqrt{h}$	1	1.414	2.0
Approximate relative crushing strength $\frac{1}{\sqrt{h}}$ =	1	.707	.5

times the height of sample (*a*) has approximately but one-half the crushing strength of the former. Other experiments indicate that similar samples (samples whose heights and bases are proportional) have the same *unit crushing load*, or require the same crushing load per square inch of the area of the base, and the total crushing load in this case is proportional to the area of the base. For example, a cube measuring 2 inches on a side requires four times the total crushing load required by a cube measuring 1 inch on a side, but the unit crushing load or load per square inch of the area of the base is the same in each. If this can be conclusively proved for small test samples, it is fair to reason by analogy that the same rule holds for mine pillars, so that if *the strength of the pillar or the unit load supported is constant for*

similar pillars, a pillar 40 feet wide in a seam 20 feet thick has the same strength as a 10-foot pillar in a 5-foot seam; or a 60-foot pillar in a 15-foot seam has the same strength as a 40-foot pillar in a 10-foot seam; the unit load supported, or the load per square foot of pillar, being the same in each case.

Also, if this be so, the crushing strength of any coal pillar, per square inch, can be found by multiplying the crushing strength of a unit cube 1 inch on a side by the square root of the ratio of the area of the base to the height of the pillar. The crushing strength of the unit cube as given by these experiments is 4,000 pounds. The unit loads producing the first crack; that is, when the coal begins to scale off on the outside of the block, are approximately one-half of the unit crushing loads in each case, except in sample (*c*), Fig. 26, where the height of the sample is four times the width of the base. This form, however, need not be considered in the study of the crushing strength of mine pillars, which usually have a broad base as compared to the height of the pillar, and are represented more closely by samples (*a*) and (*b*). Hence, we may assume the unit load producing the first crack in mine pillars as one-half of that obtained above, or 2,000 pounds.

45. Strength of Pillars.—The safe strength of pillars may be estimated as one-half or one-third of the squeezing strength—that is, the point at which the first cracks appear—or one-fourth to one-sixth of the crushing strength, according to the conditions of mining, that is, using the values given in Table II, the safe load for anthracite should not be estimated as greater than $\frac{2000}{3}$, say 700 pounds per square inch under adverse conditions; or, under more favorable conditions, $2{,}000 \div 2 = 1{,}000$ pounds per square inch. Expressed in tons per square foot, these values will vary from 50 to 70 tons.

If the conclusions deduced from the experiments made on anthracite are verified by other experiments, the allowable unit load on a pillar of anthracite may be expressed by a formula as follows:

$$S = C\sqrt{\frac{w}{t}}$$

hich S = unit load that can be supported, tons per square foot;

C = constant expressing safe crushing strength of a unit sample of anthracite in tons per square foot;

w = width of pillar, in feet;

t = thickness of seam, in feet.

AMPLE.—Find the safe load that can be put on anthracite pillars g a width of 20 feet in a seam 5 feet thick.

LUTION.—Substituting the given values in the formula, the safe n these pillars is

$$S = 50\sqrt{\tfrac{20}{5}} = 100 \text{ T. per sq. ft. Ans.}$$

will be observed that such a pillar will safely support the roof re found in the example given in Art. **43.**

. **Strength of Bituminous Coal.**—There are no s for bituminous coal similar to those given for anthra- and owing to the great variation in the character of dif- t bituminous coals, an average value cannot be given. der to make similar calculations for bituminous coal, of the coal from the particular mine in question must ade.

. **Calculation of Width of Pillar Required.**—It is us that the strength of mine pillars, or the safe unit load will support, as expressed in the formula in Art. **45,** ld be at least equal to the roof pressure or load per e foot resting on the pillars, as expressed by the for- in Art. **43.** Writing these two expressions equal to other, and multiplying the formula in Art. **45** by 2,000, duce tons to pounds,

$$160\,d\,\frac{w+o}{w} = 2{,}000\,C\sqrt{\frac{w}{t}} \qquad (1)$$

lling the percentage of room-pillar coal to be left J, ssed decimally,

$$J = \frac{w}{w+o} \qquad (2)$$

rmula **1** may then be written,

$$w = \left(\frac{160\,d}{2{,}000\,CJ}\right)^2 t; \qquad (3)$$

in which w = width of pillar, in feet;
J = percentage of coal in room pillars;
d = depth of cover in feet;
C = constant for safe unit crushing strength of coal;
t = thickness of coal seam in feet.

The percentage of pillar coal to be left between the rooms is often assumed and it depends, of course, on the relative size of pillar and room openings. The safe width of opening is best determined by practical experience and judgment. Having decided the width of opening to be adopted, this value is substituted for o, in formula **2**. The width of pillar w must be such that its value will satisfy both formulas **2** and **3**. This value can only be ascertained by substituting a trial value in formula **2**, and finding the corresponding value of J, which, when substituted in formula **3**, will give a value for w that more or less closely approaches the trial value assumed. A few trials will make known the correct value for w, or the width of pillar required. An example will make the use of these formulas clear.

Example.—Assume that a 16-foot seam of anthracite lying 600 feet below the surface is overlaid with alternate layers of shale and sand rock. Find the width of pillar that should be left between the rooms if the rooms are made 20 feet wide.

Solution.—Substituting in formula **2**, the value assumed for o, 20 ft., and assuming a trial width for the room pillars $w = 40$ ft., $J = \frac{40}{40+20} = \frac{2}{3}$, or $66\frac{2}{3}$ per cent. Then, substituting this value for J and the other given values, in formula **3**,

$$w = \left(\frac{160 \times 600}{2{,}000 \times 50 \times \frac{2}{3}}\right)^2 \times 16 = \left(\frac{160 \times 600 \times 3}{2{,}000 \times 50 \times 2}\right)^2 \times 16 = 23+ \text{ ft.}$$

This value is considerably below the assumed trial value ($w = 40$ ft.); hence, for a second trial, assuming $w = 35$ and substituting in formula **2**, $J = \frac{35}{35+20} = \frac{7}{11}$, or 63+ per cent.; and again substituting this value in formula **3**,

$$w = \left(\frac{160 \times 600 \times 11}{2{,}000 \times 50 \times 7}\right)^2 \times 16 = 36.4 \text{ ft.}$$

This value being somewhat above the assumed trial value ($w = 35$ ft.), a closer approximation may be obtained if desired, by assuming a third

al, $w = 36$, which substituted in formula **2** gives, $J = \frac{36}{36 + 20} = \frac{9}{14}$ 64+ per cent., and substituting again in formula **1**,

$$w = \left(\frac{160 \times 600 \times 14}{2{,}000 \times 50 \times 9}\right)^2 \times 16 = 35.68 \text{ ft.}$$

The correct width for room pillars in this case is, therefore, 36 ft., e width of opening being 20 ft.; or the rooms are driven on 36 + 20 56-ft. centers. Ans.

EFFECT OF REMOVING THE COAL

48. Settlement.—The removal of the coal not only creases the roof pressure on the pillars in the ratio $\frac{w + o}{w}$, s explained in Art. **43**, but it may also produce a sagging f the roof and a slight heaving of the floor, as shown in ig. 27, where the dotted lines $a\,b$ and $c\,d$ indicate the riginal roof and floor lines of the seam, respectively. The oal in the pillars supporting the roof may also be slightly ompressed by the increased weight on the pillars. Anthracite

FIG. 27

as been compressed in a testing machine, without crushing, n amount equal to one thirty-sixth of the thickness of the pecimen tested, but it cannot be assumed that all anthracite nay be compressed an equal amount, as the experiments nade were not general enough to warrant general conclusions.

The sagging of the roof, the heaving of the floor, and the ompression of the coal are the natural results produced by he great weight of the overlying rocks and their combined ffect is known as *settlement*, or the settling of the roof. When the pillars left for the support of the roof are of ample ize and their factor of safety is large, the settlement is very mall; but when the pillars are too small so that the weight n the pillars is nearly equal to their crushing strength, the

amount of settlement is often considerable and may result in a *creep* or a *squeeze*, the effect of which may be felt even at the surface.

49. The **effect on the surface** of this settling depends on the amount and character of the cover, and on the thickness of the coal bed. If overlying rocks break easily, since this broken rock occupies more space than the solid, the worked-out place will soon fill with broken rock and the effect of the settling will not be felt for any great distance above the bed. On the other hand, if the cover rock does not break readily, the whole top may settle bodily without breaking and the effect may then be felt through a great thickness of cover above the section where first settlement takes place.

EFFECT OF TOO SMALL PILLARS

50. Squeeze.—When the roof and floor are strong and unyielding and the pillars are insufficient to withstand the pressure thrown on them, they are filled with breaks and cracks, large pieces split off, and the pillars are finally crushed into small coal and the roof comes down. This is known as a **squeeze, thrust,** or a **crush.**

51. Creep.—When the material composing the floor or roof, or both, is soft and weak and the pillars left are too small, the weight on them causes the roof to sag, or the floor to bulge, or both. This result is known as a **creep.**

FIG. 28

The soft character of the floor or roof permits the pillars under the enormous roof pressure either to sink into the floor or to be forced into the roof, pressing out the softer material, which fills the openings. Fireclay is particularly susceptible to creep, and many of the fireclays that are hard when dry become extremely soft and plastic when moist. It is important to keep such a clay bottom dry.

Fig. 28 illustrates the progress of a creep. At *a*, the floor just beginning to rise or heave; but at *g*, not only is the pening entirely blocked but the pillar has also been crushed. The terms squeeze, thrust, crush, and creep are often incorectly used synonymously. A squeeze and a creep may be oing on at the same time. A squeeze or a creep does not enerally come suddenly, but the pillars and timbers usually ive evidence of the too great roof pressure by cracking and y pieces flaking off the sides. The chipping or nicking of e pillar coal, indicating that the pillars are too small, should ot be mistaken for the gradual spalling or chipping due to eathering alone. When pillars or timbers thus give evience of increased pressure, they are sometimes said to be *king the weight*. The coming of a squeeze is often first old by the departure of the rats from the affected area, as eir sense of hearing is more acute than man's; next, the oal begins to crack; and then the timbers split and crush.

52. Stopping a Squeeze.—When any sign of a squeeze ppears, the pillars should be reenforced as much as possible y wooden chocks, or ibs, Fig. 29, and by pports of any kind at can be put up just utside of the part fected. If the action f the squeeze is ow, some of the pilrs may be removed pidly, which will low the top to break

FIG. 29

d thus relieve the standing pillars of part of the weight. The treatment of a squeeze should be determined by the spection of an accurate and complete map of the workings. the disturbed region cannot be isolated by timbering and ilding strong stoppings in all the roads round about it, the ouble may often be stopped with little expense by drawing t some the timber already in place, and throwing the weight

on some small outlying patches of coal that can, with advantage, be sacrificed to save the roads and pillars of the district affected. In many cases, such trouble can more quickly be arrested by helping it than by trying to prevent it. When once the roof becomes unsteady and the timbers are breaking and the floor is lifting, a force is operating that cannot be stopped by artificial means; it can however, be directed by assisting it to find relief where the least damage will be done. If the roof does not break readily, dynamite should be used at different points to start the fall. By this means, the power of the squeeze may be broken and the danger of its spreading to adjacent workings lessened. The building of large cribs to avoid the disastrous results of squeeze often acts to increase the evil rather than to diminish it, especially if the cribs are placed at points where complete settlement is desired. The cribs are not easily removed, and serve as fulcrums by which the weight is carried forwards to other points. As permanent supports for the roof, cribs are of great advantage, but care should be taken to break the roof back of them when the weight comes on, in the same manner as over entry pillars, by the use of shots placed in the roof near them. Confining a squeeze to a certain limit is a difficult, expensive, and dangerous operation, requiring the utmost skill and care in every individual engaged in the work.

The creep will continue until the excavations are filled, and the whole becomes compact enough to resist the weight. This sometimes takes many months, but it is a sure result, be the action fast or slow. A creep cannot be resisted unless the space from which the coal has been removed is filled with other material like culm, as is explained under Flushing Culm.

53. Reserve Pillars.—Extra large pillars of coal, called **reserve pillars**, are often left at regular intervals in the workings; their purpose is to divide the mine into sections or districts so as to localize the effect of any squeeze that may start in one of these districts by breaking the roof

at the reserve pillar. These pillars are usually equal to the width of one room and two pillars, and are formed by not driving one room as called for by the plan of the mine. They are taken out before the entry or gangway is abandoned.

54. Chain Pillar.—A large pillar, called a **chain pillar**, is usually left across the ends of a group of rooms to

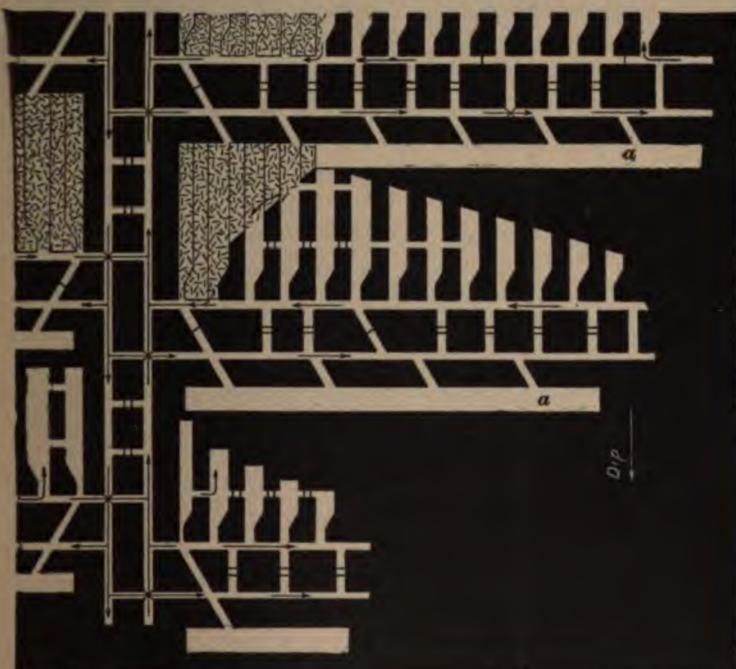


Fig. 30

protect the gangway, or entry toward which the rooms are being driven. The miners frequently drive their rooms too far and hole through into the next gangway in spite of the precautions that are taken to prevent this occurrence. To avoid the possibility of rooms being driven too far and holing through the chain pillar, a **cut-off room** *a*, Fig. 30, is sometimes driven parallel to the entries or gangways.

This place is driven wide enough to avoid the expense of yardage, and rooms driven from the next gangway are allowed to hole into it, thus avoiding the necessity of accurately measuring the length of the rooms and of carefully watching the miners to see that they do not exceed the limit allowed. The method also possesses the advantage of giving a regular width to the entry pillar and thereby avoiding the loss of a considerable amount of pillar coal when these entries are abandoned and their pillars drawn. In drawing back an ordinary chain pillar, any irregularity in the width of the pillar may cause a loss of some of the coal, which cannot occur when a cut-off room is driven as described.

55. Reopening a District Closed by Squeeze.—Time should be given for the complete settlement of the roof before any attempt is made to reopen a district thus closed, for if work is begun before the action of the squeeze has wholly ceased, the movement will begin again and may extend to other parts of the mine. The work of reopening is expensive and seldom pays in thin seams unless the coal is very valuable. Where the entries are wholly closed, it is often possible to drive a new entry in the old pillars, or even across the pillars.

It is not usually economical to attempt to reopen old entries closed, or partially closed, by squeeze, as a larger amount of material must be handled, and more timber will be required than when a new opening is driven.

In the treatment of creep, it is usually better to excavate in the roof and leave the bottom undisturbed as the bottom often keeps working and fills up about as rapidly as it can be taken out.

Whenever practicable, the work of reopening can be done to better advantage by driving a pair of entries beyond the affected district, and coming back on the coal. By this means, the least affected portion of the district will be reached first and as much of the coal recovered as is found desirable; the demand for coal, however, will not always permit the adoption of this method.

FLUSHING CULM

56. The most effectual method of stopping or controlling a squeeze or creep is to fill the rooms, and other openings if necessary, with fine material, which forms a compact mass almost as hard as the original coal. This method has been very successfully operated in the anthracite mines of Pennsylvania, where the old culm and waste banks furnish material excellently adapted for this purpose. The method is known as **culm flushing**, as the fine material is run into the mine by means of water. The fine culm from a tank or from the culm bank is flushed by means of a stream of water into the mine workings, through a pipe leading down the shaft, or down a drill hole. The head under which the

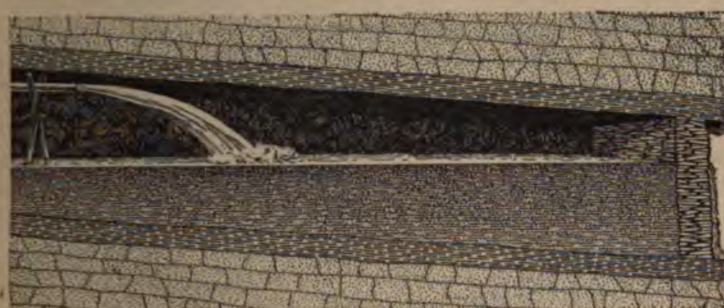


FIG. 31

system is operated causes a strong flow through the pipes, which extend from the bottom of the shaft or drill hole, along the gangways to the workings where the filling is to be made. When the seam has any considerable inclination, the end of the pipe is simply introduced near the roof and at the highest point of the chamber to be filled, the lower end of the chamber having been first closed sufficiently tight to prevent the escape of the fine culm at that point, by a battery of timbers and lagging, or by a rough wall of slate and mine rubbish through which the water filters, while the culm is dammed back. The solid material settles very compactly until the entire opening is filled. Where the inclination of

the seam is not sufficient so that the culm will be carried forwards to the dam at the face of the opening, the pipe is extended into the chamber and the end supported near the roof, as shown in Fig. 31. In this case, it is necessary, from time to time, as the filling progresses, to enter the chamber, and to disconnect and remove the end sections of the pipe. The water used in flushing drains from the flushed workings into the gangway ditches is carried to the sump, where it is pumped to the surface with the regular mine drainage. This increases the work of the pumps, but the advantages gained by flushing more than compensate for the greater expense of pumping.

57. Flushing Materials.—The water used should be the best it is possible to obtain; acid water from the mines corrodes the pipes rapidly and greatly increases the cost of the system. The quantity of water used must be sufficient to keep the pipe from blocking, and this amount is best determined by experiment in each particular case. The quantity of culm furnished to a constant stream of water may be increased up to the point where the pipe shows a tendency to block or clog, when the supply of culm must be shut off until the pipe can free itself. The quantity of water flowing through a given pipe may be calculated very approximately in any given flushing system if the size of pipe and the head are known, by means of the formulas given in *Hydromechanics* for the flow of water through a pipe. Having determined the quantity of water that will flow through the pipe in a given time, the quantity of culm that this water will carry will vary from 1 to 6 pounds of culm per gallon of water, the amount depending on the velocity of the flow. The flow of the water must always be maintained until all the culm is washed out of the pipe, or otherwise the culm will settle in the low places in the pipe when the flow of water ceases, and the pipe must then be disconnected and cleaned before operations can be resumed.

The smaller the size of the grains of the flushed material, the better the results obtained, as the fine material flows

more regularly through the pipes and produces, less frequent clogging and a larger amount of the material is carried per gallon of water used; the finer material also makes a more compact filling and less settlement of the roof results. In many cases, it is economical to employ corrugated rolls for crushing to a uniform size the material to be flushed. In the flushing of culm directly from the bank when crushers are not employed, the pipes are apt to clog, causing a serious delay while the pipes are being cleaned.

Wrought-iron, steel, cast-iron and wood pipes have been used. The life of the pipes depends on the kind of water used and the material flushed. When the material flushed is gritty, and especially when it contains ashes, clinker, etc., the life of the pipes is much decreased.

58. Results of Flushing.—The material flushed into mine openings, as described, forms a very compact mass. The exact strength of the flushed material to resist compression is not known, but the following experiment gives an indication of what may be expected. A cubic foot of coal was ground fine and flushed into a box having a square section 12 in. × 12 in.; the flushed material filled the box to a depth of 17½ inches, showing an increase in volume by crushing of about 46 per cent. Assuming a similar condition of the material flushed into mine openings, it would require a settlement of 5½ feet for every 17½ feet of thickness in the seam, to compress the flushed material to the hardness of the original coal, or a settlement of about 31 per cent. of the thickness of the seam.

Experiments have shown that dry culm will support from two to three times as much weight as wet culm. When dry, it is packed so firmly that gangways may be driven through it with vertical walls of culm on either side that show only a slight tendency to caving. It requires, however, a long time for culm to dry after it is flushed into the mine, and wet culm must therefore usually be depended on to withstand the weight of a mine squeeze. The chief advantage of flushing consists in the completeness with which the flushed material

enters and fills the small cracks and crevices of pillars, and the compactness with which the material surrounds and supports a weak pillar.

By examining a mine map, the weak points can usually be picked out; and by flushing them with culm, a squeeze can frequently be prevented and even arrested after it is once started. If the rooms are completely filled with culm, the roof can settle only a small amount, probably not more than 3 to 7 per cent. of the thickness of the bed. This method has been found most efficient in mines where a large amount of pillar coal had been left, for by flushing all or a part of an effected area the roadways through this portion of the mine can be kept open, and in many cases the pillars themselves can be afterwards taken out.

59. Effect of Flushing to Extinguish Mine Fires. At first, it was feared that culm flushed into the workings would take fire by spontaneous combustion, but experience has proved that this does not occur, as the culm packs so closely as to exclude the air necessary for spontaneous combustion. On the other hand, the wet flushed material affords the best known means for the total extinguishment of mine fires existing in the gob or waste heaps, or in the coal in the mine workings. As the fine flushed material penetrates the smallest cracks and crevices of the pillars, gob heaps, etc., it is possible often to completely isolate a fire by flushing a few rooms and passages surrounding the fire. Flushing for this purpose has proved even more efficacious than flooding the mine, as workings that have been flooded for 3 months have been found to still be on fire when the water was pumped out. Moreover, the flushed portion of the mine is in condition for work to begin on the pillars at any time when desired, while the flooding of a mine, or any portion of it, results in a large amount of damage, and a heavy expense is necessary before operations can be resumed in the workings.

60. Drawing Pillars After Flushing the Openings. The method of flushing the openings with culm before drawing pillars has several advantages: The pillar coal is more

npletely recovered and in better condition; the work of wing back the pillars is attended with less danger to rkmen; and the surface is less damaged. The general thod of proceeding is to drive a narrow opening up the ter of the pillar, leaving a thin rib of coal on each side en necessary to support the flushed material. This terial, when fine, will be very largely self-supporting, and this case it will not be necessary to leave a rib of coal at sides of the pillar. Timbers are placed flush up against culm, or against the rib coal, as the case may be. If the shing material shows any tendency to run, lagging is

FIG. 32

FIG. 33

ced back of the timbers. As the work progresses, the tlement on the culm causes the timber to break, and it l generally be necessary to place new timbers between broken ones in order to keep the road open while the lar is being drawn. The settlement of the roof will gen-lly be about 25 per cent. of the height of the seam. Fig. 32 ows the flushed openings of a mine before the work of lar drawing is begun. Fig. 33 shows the same section of mine after the pillars are drawn, and the openings thus de flushed with culm. Each breast is holed through into upper gangway as shown at *a*, so that the flushing pipe ly be carried in through this opening, or a single opening

may serve for a number of breasts, the flushing pipe being carried through the cross-cuts at the head of the breasts. The opening in the first pillar on the left *b* has been left open and protected by comparatively heavy ribs of coal, in order to provide a roadway for the working of the coal in the chain pillar *c*. A skip has also been taken off of the lower side of the gangway pillar.

SHAFT PILLARS

61. The coal left in the seam around the shaft to prevent the shaft from being injured by any settlement or cracking of the strata and to protect any buildings on the surface above the shaft forms what is called a **shaft pillar.**

As is shown in Fig. 34, in addition to the breaking and arching of the roof material immediately above an opening in the coal bed, the effect of thus taking out a portion of the bed may be felt in one of two ways and for a distance away from the opening, depending on the width of the opening and the nature of the overlying rock. As shown in Fig. 34 (*a*), the overlying strata may subside bodily, producing a depression on the surface, as shown; or, as is shown in Fig. 34 (*b*), the strata above the opening may be cracked in irregular lines radiating more or less from the opening. These cracks may extend to the surface and there cause more or less of a subsidence, or they may peter out before reaching the surface, dependent on the depth of cover and on the nature of the rock. If the rocks overlying the excavation are fragile, so that they crack and break easily, due to the subsidence, the effect of the subsidence will not be felt to so great a distance as when the rocks are firm and settle bodily, as in the former case the broken rock occupies more space than the solid and consequently the opening is very soon filled with this broken rock and further subsidence, or draw, prevented.

The effect on the overlying rock due to the excavation of all or a part of the bed is known as the **draw,** whether it be a subsidence, as shown in Fig. 34 (*a*), or a cracking, as shown in Fig. 34 (*b*). There is no certainty of the direction the

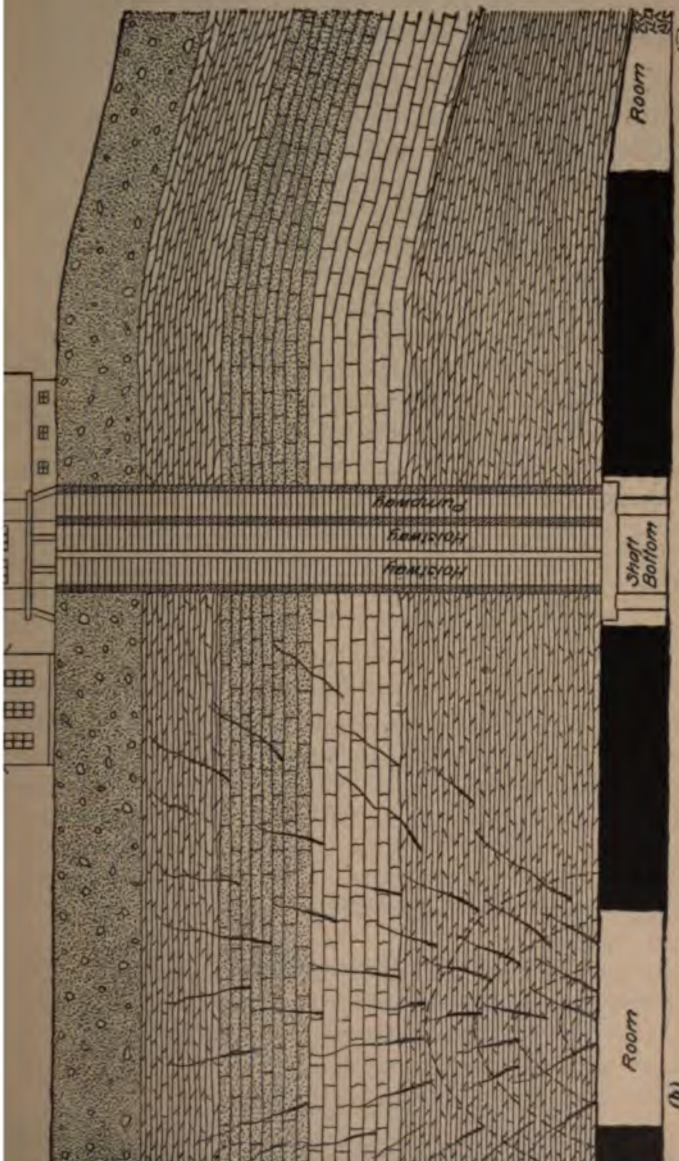


Fig. 34

draw will take, as this depends solely on the natural conditions existing in the roof strata.

62. Size of Shaft Pillar.—Great diversity of opinion exists among mining authorities as to the size of shaft pillars and the matter must be decided largely by local considerations and practical experience in the district in which the shaft is sunk. The shaft pillar should be large enough so that the effect of this draw cannot reach the shaft or the buildings on the surface about the shaft and thus interfere with its alinement.

An accident to a shaft due to too small a pillar entails great expense and may mean the loss of the shaft, hence a large factor of safety should be used in determining the size of the pillar, particularly since the effect of the draw cannot be accurately foreseen. The same general rules apply to shaft pillars as to other pillars; namely, in general, the deeper the shaft and the thicker the seam the larger must the pillar be, while the harder the coal the smaller the pillar.

In flat seams, the size of the shaft pillar required depends chiefly on the depth of the seam below the surface, that is, the depth of cover, and to a less extent on the thickness of the seam. Numerous rules given by different authorities for determining the size of the shaft pillar afford widely varying results, owing to the varying conditions under which each rule was formulated, and for this purpose that rule should be employed that seems best suited to the particular conditions of the case. For the sake of comparison, a number of these rules are given as formulas and the results obtained by applying the formulas to determine the shaft pillars required at depths of 300 feet and 600 feet, respectively, are tabulated in Table III.

In the formulas, the following symbols are used:

D = diameter of round pillar, or side of square pillar, in yards;

d = depth of cover, in yards;

t = thickness of seam, in yards.

NOTE.—Each rule is stated as usually given, but for the sake of conformity the formulas in each case express the rule in yards, and give the value for the diameter of a circular pillar, or the side of a square pillar.

erivale's Rule.—*Diameter of circular pillar, or side ? pillar, in yards, is equal to twenty-two times the square he depth of the shaft, in fathoms, divided by 50.*

$$D = 22\sqrt{\frac{d^\bullet}{2 \times 50}} \qquad (1)$$

e's Rule.—*Minimum diameter of circular pillar, or quare pillar, 35 yards to a depth of 150 yards; add for each 25 yards of additional depth.*

$$D = 35 + 5\left(\frac{d - 150}{25}\right) \qquad (2)$$

le's Rule.—*Minimum diameter of circular pillar, or quare pillar, 40 yards to a depth of 60 fathoms; add for each 20 fathoms of additional depth.*

$$D = 40 + 10\left(\frac{d - 2 \times 60}{2 \times 20}\right) \qquad (3)$$

ely's Rule.—*Minimum diameter of circular pillar, or quare pillar, 40 yards to a depth of 100 yards, add for each 20 yards of additional depth.*

$$D = 40 + 5\left(\frac{d - 100}{20}\right) \qquad (4)$$

ig Engineering (London) Rule.—*Radius of circu- ır, or half side of square pillar, in yards, is equal to plus one-tenth of the product obtained by multiplying of shaft, in yards, by the square root of the thickness m, in yards.*

$$D = 40 + \frac{d \times \sqrt{t}}{5} \qquad (5)$$

r's Rule.—*Radius of circular pillar, or half side of illar, in feet, is equal to three times the square root of ıct of the depth of cover, in feet, and the thickness of the feet.*

$$D = 6\sqrt{d \times t} \qquad (6)$$

's Rule.—*Draw a line enclosing all surface buildings ıld be protected by the shaft pillar. Make the pillar of*

such size that solid coal will be left in all around this line for a distance equal to one-third of the depth of the shaft.

Calling s the diameter of the circle, or the side of the square, in yards, at the surface, we have,

$$D = s + \frac{2d}{3} \qquad (7)$$

Hughes's Rule.—*For the diameter of a circular pillar, or the side of a square pillar, allow 1 yard for each yard in depth.*

$$D = d \qquad (8)$$

Central Coal Basin Rule.—In the Central Coal Basin of the United States, for shaft mines worked on the room-and-pillar method, the rule is: *Leave 100 square feet of coal for each foot that the shaft is deep, it being understood that a main entry of average width is driven through this pillar. If the bottom is soft, the result given by this rule is increased by one-half.*

$$D = \sqrt{\frac{100 \times d}{3}} \qquad (9)$$

TABLE III

Authority	Diameter or Side of Pillar Yards	
	Shaft 100 Yards Deep	Shaft 200 Yards Deep
Merivale	22.0	31.00
Andre	35.0	45.00
Wardle	40.0	60.00
Pamely	40.0	65.00
Mining Engineering (London)†	68.3	96.50
Foster†	84.8	120.00
Dron*	100.0	166.66
Hughes	100.0	200.00
Central basin	100.0	142.00

* An allowance of 100 feet has been made for the diameter of the circle, or side of the square, enclosing the buildings on the surface.

† The seam is assumed to be 2 yards (6 feet) in thickness.

In the use of formulas **2**, **3**, and **4**, negative results in the fractional part must be rejected as the diameter of pillar cannot be less than the minimum diameter or side allowed by the rule. For example, it is useless to apply Andre's rule to depths less than 150 yards, Wardle's rule to depths less than 60 fathoms (120 yards), or Pamely's rule to depths less than 100 yards.

Table III shows clearly that no hard and fast rule can be given for determining the size of shaft pillar required in any particular case. The rules stated, however, determine the size of pillar required within certain practical limits, and suited to different conditions of roof strata, and are, therefore, useful and desirable. The presence of faults or slips in the roof makes larger pillars necessary.

63. Pillars to Support Buildings, Bodies of Water, Etc.—What has been said in reference to shaft pillars, applies likewise in reference to pillars required for the support of buildings, ponds, lakes, or other bodies of water. In all these cases, Dron's rule is perhaps the most practicable, since it provides for a given pillar of coal all around the area to be supported.

64. Shaft Pillars in Inclined Seams.—The inclination of the seam increases the uncertainty in respect to the draw in the strata overlying the seam, making it more difficult to give any rule of universal application. The general practice in regard to the size of pillar required when the seam is inclined, is to increase the pillar on the rise side of the shaft, while that on the dip side of the shaft is often made the same as for a flat seam. To what extent it is necessary to increase the pillar on the rise side is largely a matter of experience and judgment in particular localities, and this is always the most reliable guide.

It is desirable, however, to give some approximate rules for pillar calculations that may be used as a guide in localities where the conditions are not known, particularly since questions involving such theoretical calculations are often given in examinations. One rule that has been

suggested is to calculate the extent of the pillar on the dip side of the shaft by the rules previously given for flat seams, choosing for this purpose the rule that seems best suited to the conditions with respect to the character of the seam and overlying strata. The diameter of the circular pillar, or the side of a square pillar, thus obtained, will give the width of the pillar measured on the *strike* of the seam, and half of this width will give the extent of the pillar measured below the shaft on the *dip* of the seam. Then, as before, calling the width of the pillar D, the depth of the shaft d, and the inclination of the seam a, the extent of the pillar measured on the pitch of the seam may be taken as $\frac{D}{2} + \frac{3}{4} d \sin a$. This rule is simply arbitrary, but approximates to a certain extent the condition relative to the inclination of the seam. It must be remembered that all the rules and formulas given for determining the sizes of pillars, both in flat and inclined seams, are only suggestive of what is required, and must always be modified according to the experience and judgment of the person in charge of the work.

65. Slope Pillars.—A slope should have a pillar along its full length and theoretically these pillars should gradually increase in width from top to bottom as the thickness of cover increases, but in practice this is seldom done and the slope pillar is the same width throughout. The frequency of squeezes on slopes indicates that this is faulty practice. The width of the slope pillar is sometimes prescribed by law.

There is not much danger of the draw destroying a slope sunk in the coal, except that due to mining in an underlying seam, because the line of the slope is in the same plane as the bed in which the mining is done and nearly at right angles to the plane of fracture, whereas in a shaft, the lines of fracture may reach or cross the line of the shaft, and in a pitching seam this danger is even greater than in a flat seam.

66. Entry Pillars.—Much that has been said with reference to room and slope pillars will apply with equal force to entry pillars. As in the case of room pillars so in that

of entry pillars, the chief factors determining the width of pillar required are the depth of cover, thickness, and character of coal seam and width of opening. The size of entry pillars, as of room pillars, is determined almost entirely by practical experience. The best practice advises leaving large pillars about the entries and all airways so as to avoid all possibility of a squeeze.

67. Barrier Pillars.—The laws of some states require a pillar of coal to be left in each bed of coal worked along the line of adjoining properties, of such width, that, taken in connection with the pillar to be left by the adjacent property owner, it will be a sufficient barrier for the safety of the employes of mines on either property in case one should be abandoned and allowed to fill with water. These pillars are known as **barrier pillars.** The width of such pillars is determined by the engineers of the adjoining property owners and the mine inspector in whose district the properties are located.

An arbitrary rule for the width of barrier pillars, adopted by a number of coal companies and by the State Mine Inspectors of the anthracite districts of Eastern Pennsylvania, is as follows:

Rule.—*Multiply the thickness of the deposit, in feet, by 1 per cent. of the depth below drainage level, and add to this five times the thickness of the bed.*

Thus, for a bed of coal 6 feet thick and 400 feet below drainage level, the barrier pillar will, according to this rule, be $(6 \times 400 \times .01) + (6 \times 5) = 54$ feet wide.

The Bituminous Mine Law of Pennsylvania requires a thickness of 1 foot of pillar for each $1\frac{1}{4}$ feet of water head if, in the judgment of the engineer of the property and of the district mine inspector, this thickness is necessary for the safety of the persons working in the mine. The same law makes it lawful for any operator whose mine is endangered by an accumulation of water in abandoned workings located on an adjoining property, to drive a drift or entry protected by bore holes, across the barrier line, for the

purpose of tapping and draining such water, and makes unlawful for any person to attempt to, or in any way obstruct the flow of such water to a point of drainage. The law also provides that no coal shall be mined within 50 feet of any abandoned workings containing a dangerous accumulation of water, until such danger has been removed as described above.

68. Data for Width of Pillar.—Table IV gives data for the sizes of rooms and pillars for a number of the coal-mining regions of the United States. The dimensions given are averages for the particular region named for mines that have been worked successfully and without squeezes. They are, therefore, useful as a guide in laying out a mine where the conditions are similar to those given.

A number of formulas have been given by different writers, but these apply to given localities and are not universal in their application.

8-40

p60a

	Locality	Amount of Cover Feet	When Are Pillars Drawn?	Width of Stump Pillar Between Entry and Room Feet	Per Cent. of Coal Left in First Working	Total Per Cent. of Coal Recovered	Distance Between Cross-Headings Feet	Width of Entries Feet	Width of Main Entry Pillar	Width of Pillar Between Cross-Entry and Air-Course Feet
Alabama	Ne[illegible] se[illegible]	[illegible]00—600	Retreating	21	40	85	326	8	30	15
	Th[illegible]	[illegible]0—300	Retreating	20	30	90	300	8	20	10
	Blu[illegible]	[illegible]0—400	As soon as room is driven up	50	35	85	300	8	24	12
	Bl[illegible]	[illegible]0—600	As soon as room is driven up	25	30	80	250	8	30	12

METHODS OF WORKING

(PART 2)

MODIFICATIONS OF ROOM-AND-PILLAR METHOD

PILLAR-AND-STALL SYSTEM

1. The **pillar-and-stall system**, also known as **post-and-stall**, **board-and-pillar**, or **stoop-and-room**, is a

FIG. 1

FIG. 2

modification of the general room-and-pillar method in which the openings, usually called *stalls* or *rooms* in America, are narrow, rarely exceeding 4 or 5 yards in width. The pillars

are at least as wide and usually wider than the stalls. In the *single-stall system*, the stalls are turned narrow off the entry as shown in Fig. 1, and widened inside as described in room-and-pillar work. In the *double-stall system*, Fig. 2, the openings are wider, and are similar in every respect to double rooms, except that the pillars separating the double stalls are generally wider in proportion to the width of the stalls than are the pillars separating rooms. In double-stall work, the openings are often 12 or 15 yards in width, the roof being supported on good pack walls in the center of the stall; the pillars often reach a width of 30 yards. The pillar-and-stall system is adapted to weak roof and floor, to strong roof and soft bottom, to soft, brittle coal, and in general to conditions requiring ample support of the roof; the system is particularly useful in deep seams where the roof pressure is great.

2. The method of mining in the Connellsville and Pittsburg regions of Pennsylvania very closely approaches the

FIG. 3

English and Scotch pillar-and-stall method. The coal dips from 5° to 12° and is from 8 to 11 feet thick, but only from 6 to 8 feet are taken out, as the top coal is badly mixed with slate. The rooms, Fig. 3, are opened up with a narrow neck, and although widened out, they are driven only about

12 feet wide for their full length. Where the cover is not over 350 feet, the pillars are 30 feet wide, as shown in section *A*. Where the cover is over 350 feet, only every other room is driven, as shown in section *B*, thus leaving pillars 72 feet wide. The method of drawing back the pillars is shown by the broken lines.

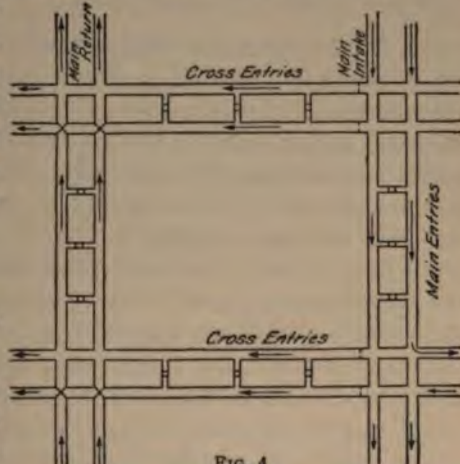


FIG. 4

PANEL SYSTEM

3. In the **panel system**, the coal area is first blocked out by pairs of entries driven at right angles to each other if possible, as shown in Fig. 4. As soon as a panel has been thus blocked out, the removal of the coal within the panel is begun by driving openings *a*, Fig. 5, from the cross-entries. These openings are connected by a cross-heading *b*, a suitable pillar being left between *b* and the cross-entry. Rooms, or stalls *c* are then opened off the heading *b* and driven almost the full length of the panel, only leaving suitable chain pillars *d* for the protection of the main and cross-headings enclosing the panel.

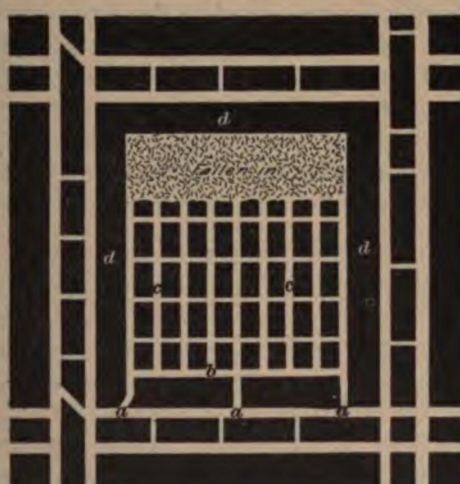


FIG. 5

After the rooms, or stalls, have been driven their full length, the pillars separating the stalls are drawn back, allowing the roof to fall as shown. The system illustrated in Fig. 3 is a modified form of the panel system.

4. When a panel is worked out, in order to close off the whole panel it is usually necessary only to put stoppings in the mouths of the openings *a*. A pipe is put through each stopping with a valve in the pipe on the outside of the stopping. As firedamp is often given off in the panel after it is worked out, these valves should be opened at regular intervals and the gas escaping tested for firedamp with a safety lamp held a few inches from the mouth of the pipe, so that the escaping gas can mix with the fresh air. If gas is found, the valve is left open and the gas allowed to escape and should be led into the return; it is sometimes lighted at the pipe and allowed to burn off, but this is dangerous, for the flame may travel back through the pipe and explode the gas in the panel. A second pipe on which is a pressure gauge is sometimes placed in the stopping to test the pressure of gas behind the stopping, particularly when the gob is on fire and generating gases. If there is much pressure of gas behind the stoppings, the pipe through the stoppings should be left open when the men are not in the mine. In some cases, the pipe through the stopping is connected with a pipe laid along the entries and leading into the return air-current.

5. The **advantages** of the panel system are: A more complete control of the ventilating current is possible, and the ventilation in any panel may be altered as circumstances may require; the powder smoke from each panel goes directly into the return air-current and does not go throughout the mine; an explosion or a fire occurring in one panel is usually confined to that panel; creeps or squeezes are of rare occurrence, and are confined to the panel in which they occur; the output of coal is better regulated and more reliable. The disadvantage of the system is the expense of entry driving, and the delayed extraction of the coal within the panel until the driving of the main and cross-headings has been completed.

INCLINED WORKINGS

6. In a general way, all seams having an inclination such that the mine car can be taken to the face of the room may be considered as **flat seams**; this includes all seams whose inclination does not exceed 10° or 12°. In an inclined coal seam, there are a number of considerations in connection with the removal of the coal that are not met with in flat workings, such as the handling of the coal from the face of the room to the gangway, the tendency of the roof to slip downwards, and the support of the workmen at the face. All these difficulties increase with the inclination.

Not only should the road or incline leading to the face have a suitable grade in favor of the loads, but the line of the working face should be such that the loose coal as mined will gravitate along the face toward the haulage road. When a road or working place is driven across the pitch, the face of the coal is generally inclined also across the pitch. In this case, the road should be located near the dip side of the breast, so as to give the greater length of breast to the rise side of the road where the loosened coal will gravitate to the car. By this means, the labor of handling the coal at the face will be greatly reduced. The mine car is sometimes hauled to the face by means of a windlass placed at the bottom of the room and a block and tackle near the face. An electric gathering locomotive, on which an electrically operated drum is mounted, is sometimes used in a similar manner, instead of the windlass, to hoist empty cars into rooms driven to the rise, and to hoist loaded cars from rooms driven to the dip, the locomotive standing on the gangway at the mouth of the room. Usually, however, when the pitch is so steep that a mule or motor cannot haul the empty car to the face of a room, the car is left at the foot of the room and the coal taken from the face to the car by a buggy, or by a chute.

BUGGY SYSTEM

7. The **buggy system** of handling coal from the face to the entry is shown in plan in Fig. 6 (*a*) and in section along the line *b d* in Fig. 6 (*b*). It may be used in thick seams pitching from 10° to 18° and where there is plenty of waste that can be used for building up the track, but it is

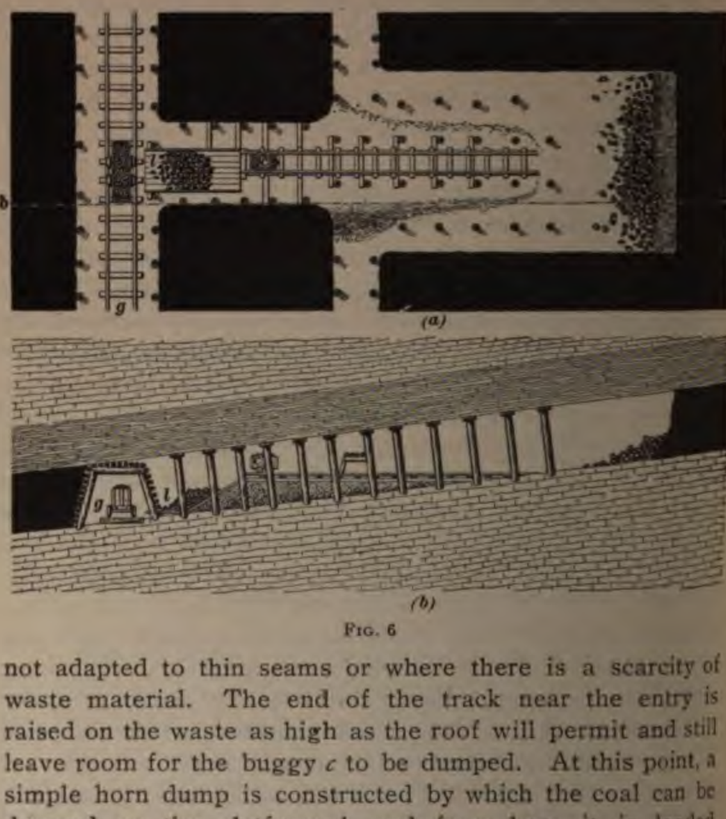


Fig. 6

not adapted to thin seams or where there is a scarcity of waste material. The end of the track near the entry is raised on the waste as high as the roof will permit and still leave room for the buggy *c* to be dumped. At this point, a simple horn dump is constructed by which the coal can be dumped on the platform *l*, and from here it is loaded into the mine car standing on the track *g*. From the dump, the track is carried back into the room on a grade such that the empty buggy can be pushed by hand up the track. If the seam is thick and not too steeply inclined, a single

section of track may extend from the platform at the bottom of the room to the face of the room, but when the coal seam is not of sufficient thickness to give the necessary headroom or is so steeply inclined that the grade of the track will be too steep, two or more sections of such roads are laid and at the bottom of each section the buggy is dumped into another buggy on the next lower section, and so on until the coal is finally dumped on the platform at the bottom

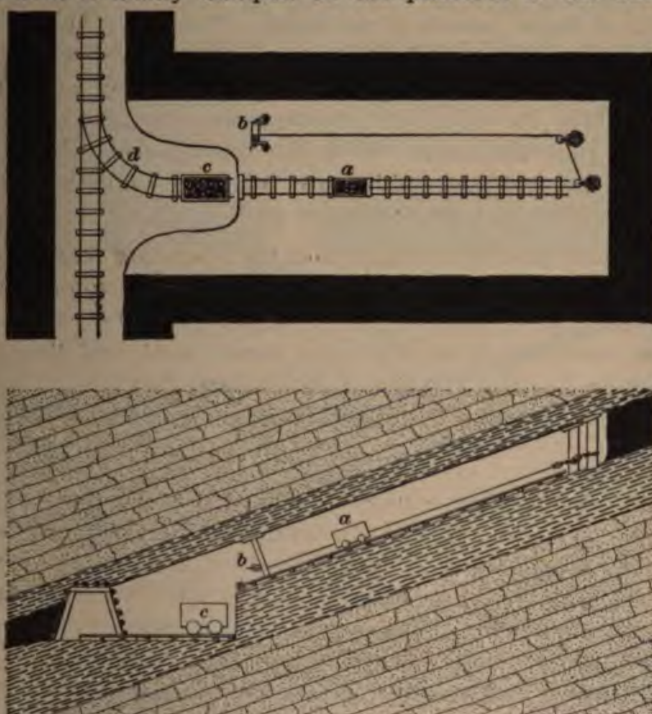


FIG. 7

of the room. Each section of track thus requires a separate buggy, and the coal must be handled as often as there are sections, greatly increasing the expense for handling and the amount of small coal due to breakage in handling.

8. Lowering Buggy by Windlass.—In thin seams, where the inclination is too steep for the mine car to be

taken to the face and where there is not sufficient headroom for a buggy track to be laid as was shown in Fig. 6, the buggy *a*, Fig. 7, may be hauled to the face by a windlass *b* located at the foot of the room and supported by two posts set firmly in the roof and floor of the seam. The buggy is dumped into the mine car *c* standing on a track *d*. The windlass is usually operated by hand, though it may be operated by a small electric or compressed-air motor when either of these powers is available. Pulleys or blocks are hung from posts near the face and are moved from time to time as the face advances. The windlass is sometimes placed near the face, but it then requires frequent resetting as the face advances. With the arrangement shown in Fig. 7, one man can readily lower a loaded buggy and hoist an empty one on a pitch as great as 15°.

9. **Self-acting inclines and jig roads** are occasionally used for getting the coal from the face of a room to the entry, but their more frequent use is for lowering the mine cars from one entry to another at a lower level, and they are therefore described in detail in *Haulage*, Part 5.

CHUTES

10. A **chute** is a narrow inclined passage down which the coal slides by gravity, or is pushed. When the pitch of the chute is between 15° and 30°, sheet iron is laid in it to furnish a good sliding surface for the coal. When the inclination is less than 20°, it is generally necessary to push the coal down the chute, as it does not then slide readily even on sheet iron. When the inclination of the chute exceeds 30°, coal will slide readily on a rock bottom without the use of sheet iron. The use of chutes is therefore limited to seams whose inclination is greater than 15°, that is, to what are generally called *steep seams*.

When the inclination of the seam is less than 30° to 35°, a single chute is usually placed in the center of the room. The chute ends in a platform projecting into the entry, and from this platform the coal can be readily loaded into the mine

car. The refuse made in mining is thrown on either side of the chute; and, if the pillars are to be robbed, this refuse should be kept as near to the center of the room as possible. Two chutes are sometimes employed, one along each rib, but as the cost of the second chute is considerable, it is not generally used unless it is required for purposes of ventilation.

11. Fig. 8 shows an inclined room with a sheet-iron

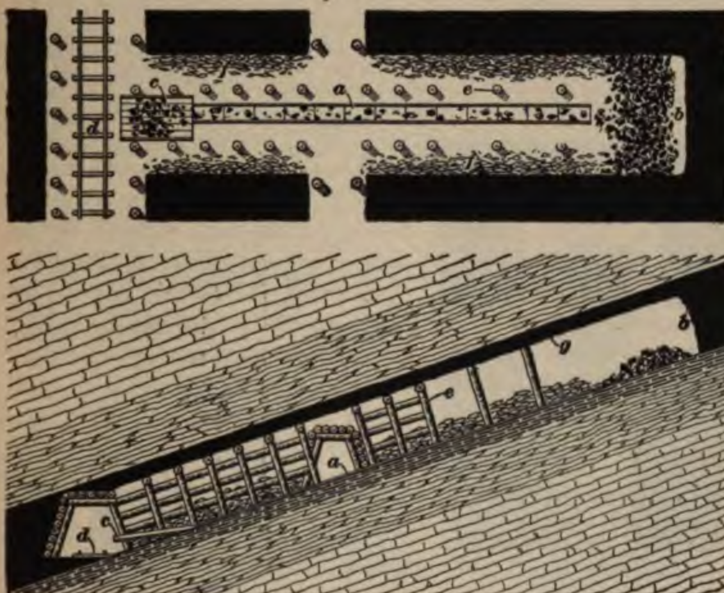


FIG. 8

chute *a* in the center. As the coal is mined at the face *b*, it is shoveled into the chute and slides by gravity to the platform *c*, from which it is shoveled into the mine cars on the track *d*. Rows of props *e* are frequently stood alongside the chute to keep up the roof above it, and the gob is stored between the posts and the rib in the spaces *f*. The chute also acts as a manway, and by means of the props the miners are able to work their way up and down the room. The top coal *g* is left up to help keep up the roof and may be taken

down after the room has been driven to its full length or it may be left in place.

12. Support for the Miners.—When the bed inclines at a greater angle than about 35°, it is necessary to provide a staging or platform of some kind on which the workmen can stand in mining the coal. A staging of timber may be built and advanced as the face advances, but this is an expensive method, and it is generally better to allow the room to fill up with the broken coal, keeping the level of this broken coal just near enough to the face to provide a standing place for the workmen. The coal is supported at the bottom of the room by a bulkhead of heavy timber known as a *battery*, and the method of working is known as *working on battery*. Only enough coal is taken out through a chute at the bottom of the room to take off the excess of coal that cannot be thus stored in the room owing to the fact that the broken coal occupies about 75 per cent. more space than the same coal in the solid. The method described in Art. 15 is also called working on battery.

Fig. 9

13. Single-Chute Rooms. Fig. 9 illustrates the general form of a single-chute room. The coal *a* is stored in the center and a manway *b* is constructed up each side with props and planking for the purpose of ventilation and to afford access to the face for the workmen. Crosscuts *c* are made by driving through the pillar separating adjacent rooms. At the point where the room neck widens to full room width, a battery is constructed to hold back the coal in the chute. This is composed of strong posts *d* set in the roof and floor of the seam as a support for the

cross-timbers *e*; a small opening *f*, known as the ***loading chute***, is left at the center of the battery and through this the coal is drawn as required. The manways *b* are connected with the room neck by a small opening in the battery, through which workmen pass in going to and from work. This opening is covered by a curtain so as to maintain the air-current along the face.

When the coal is drawn out through a central loading chute, the movement takes place principally in the coal lying near the center of the breast. If the roof is poor, the movement of the coal will not in this way cause it to fall and mix with the coal; and if the floor is soft the props protecting the chute, and which are stepped into the floor, are not so liable to be unseated, closing the manway and blocking the ventilation. The surplus coal is sometimes thrown down the manways, instead of being drawn out at the bottom of the breast through a loading chute, leaving the loose coal in the center of the breast undisturbed until the limit is reached.

14. Double-Chute Rooms.—Fig. 10 shows the arrangement of an inclined room in which the weight of the loose coal is supported mainly by a pillar of coal *a* left along the entry. The coal is drawn out of the room by two loading chutes *b*, one at each side of this pillar, and the workmen gain

FIG. 10

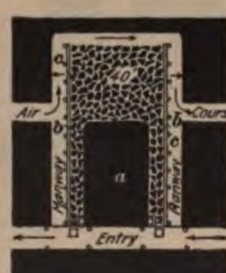


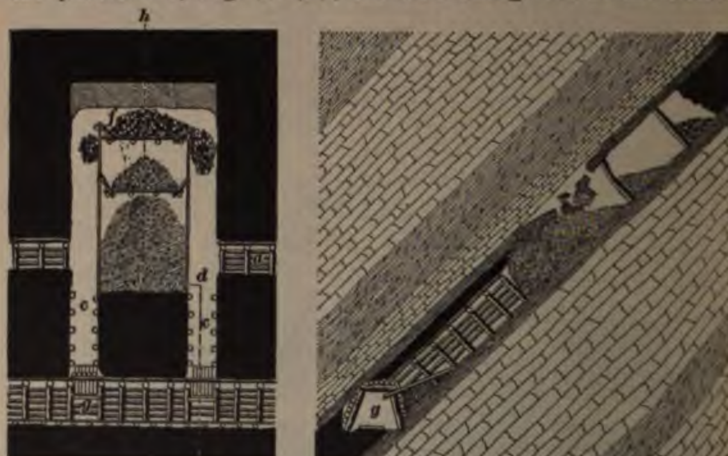
FIG. 11

access to the manways *c* along the room ribs through short manways *d* driven through the entry pillars. Fig. 11 shows a similar arrangement to that shown in Fig. 10 except that the sides of the loading chutes *b* are in line with the sides of the

chute in the room, the manways c are straight, and the loading chute and manway are in the same opening in the coal. This method has an advantage over that shown in Fig. 10, as it requires less cutting of the entry pillars.

An advantage of supporting the coal by a pillar at the bottom of the room, as shown in Fig. 25, is that there is less likelihood of a break occurring in the batteries, which would throw all of the coal on the gangway or airway, and thus close off these passages and interfere both with haulage and ventilation.

15. Separation of Coal and Rock in the Rooms.—If the coal seam is mixed with rock that can be readily separated from the coal underground, this separation may be made on the platform f, Fig. 12 (a), the rock being left in the center



(a) b FIG. 12 (b)

of the room instead of the coal, as was illustrated in Figs. 10, 11, and 12. The coal is then thrown down the chutes c and loaded into cars on the entry g. Fig. 12 (b) is a section through the room shown at (a) on the line $b\,d\,e\,h$. This method is also used where the coal is very gaseous and where it is not well, therefore, to keep broken coal stored in the room. The air-current passes through the airway a and up the chute c to the face. This method is not adapted to very

thick seams, as it is impracticable to build the necessary platforms in such seams.

16. Table I gives approximate inclinations of the seam when the several methods just described are employed. These inclinations may be varied by local conditions.

TABLE I

Method Employed	Inclination of Seam Degrees
Cars lowered by hand, or drawn by mule or motor, rooms on full pitch	0–6
Cars lowered by hand, or drawn by mule or motor, rooms at angle with pitch	5–12
Cars lowered by windlass, rooms on full pitch	5–10
Self-acting incline or jig road	5–30
Buggy system, thick seams	10–18
Sheet-iron chutes	15–30
Natural chutes with battery	30 upwards

MANWAYS FOR STEEPLY INCLINED ROOMS

17. The **manways** in steeply inclined rooms are constructed in two general ways. In a seam that is not over 6 to 8 feet thick, the method shown in Fig. 13 may be used. The posts *a* are set as shown and lined with plank; this partition forms the sides of the chute *b* and leaves a manway *c* between the chute and the rib.

Fig. 13

In thick seams, inclined posts called jugulars *a*, *a*, Fig. 14, are used. These are set in hitches cut in the floor and the rib, so as to form a triangular passageway or manway *b*. The jugulars are lined with plank to form the sides of the center

chute *c*, which is filled with loose coal or refuse, as shown in Fig. 14.

18. Length of Rooms on a Pitch.—As a general rule, in inclined seams as in flat seams, the rooms are driven up to within a short distance of the entry above, a chain pillar being left between the ends of the rooms and this entry; the width of this pillar varies with the character of the roof, floor, and coal, depth of cover, and inclination of the seam. To secure better ventilation, an occasional room is often holed through this pillar into the entry above; and where the coal has been worked out from the chambers above, and there is no water to interfere with the lower workings, many or all of the rooms are thus driven through to the upper entry. The chain pillar is sometimes drawn back with the other pillars. The distance between the successive lifts or entries varies with the conditions, but is usually about the same or slightly less than the distance between entries in flat workings under the same conditions.

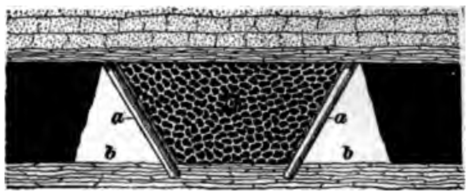


FIG. 14

PILLAR DRAWING IN INCLINED SEAMS

19. The method of drawing pillars in inclined seams differs somewhat from that used for flat seams, particularly where the inclination exceeds about 30° and where the tendency of the roof to slip downwards is stronger than on a flatter pitch. Four methods of drawing the pillar are illustrated in Fig. 15. In the first method, Fig. 15 (*a*), a narrow place *a* is driven up in a wide pillar, and the rib coal left between this place and the manway is then broken by shots placed as indicated. This operation is repeated until the pillar is removed. Another method, Fig. 15 (*b*), consists in taking a skip up the side of the pillar by shots placed in the rib. In both (*a*) and (*b*), the holes are all preferably first

drilled and then charged and fired in regular order from the bottom upwards. In the method shown in Fig. 15 (*c*), the pillar is first cut lengthwise into the smaller sections or pillars by a central narrow place *a* and cross-cuts *b*, the sections are then broken by shots placed in the corner of each small pillar, as indicated in the figure. In pillar drawing in steep seams, care is necessary to avoid being shut in by the closing of the manway; the shot firer retreats to a cross-cut below while waiting for a blast. In steep seams, it is very necessary to secure a fall of roof as each section of pillar is withdrawn, in order to cause the weight to settle

(a) (b) (c) (d)

FIG. 15

and to avoid the risk of the sliding of the roof on the pillars. In working pillars on a pitch, those farthest up the pitch should be drawn first and a lower range should not be commenced until those immediately above are finished.

In very jointy or free seams of coal, or where the coal is shelly, the pillar coal very often starts to run, so that very little mining need be done in drawing back the pillars. Drawing the pillars in coal of this character, while very easy, is extremely dangerous and calls for great caution. Fig. 15 (*d*) shows a pillar in which the coal has thus begun to run.

ANTHRACITE MINING METHODS

20. The geological disturbance that is in a large measure responsible for the formation of anthracite has also inclined more or less steeply most of the anthracite measures, and a perfectly flat anthracite mine is seldom found in America. Even where a portion of a seam may be comparatively flat, such sudden changes in dip must be expected that a system adapted to working on a pitch is almost universally used. On the other hand, most of the bituminous mining in the United States is in comparatively flat measures; and where steeply inclined bituminous seams are worked, the methods adopted are similar to those used in working anthracite, except such slight modifications as the difference in the nature of the coal requires. The method of mining steep anthracite beds may therefore be considered as typical of American methods of mining steeply inclined beds. The room-and-pillar method modified to suit local conditions is the one universally used in America for the underground mining of anthracite.

The rooms in an anthracite mine are called *breasts* (or chambers); the haulage ways are called *gangways* instead of entries or headings as in bituminous mines; the cross-cuts or break-throughs between the breasts are usually called *headings*. A mine is usually divided into *lifts* by gangways driven off both sides of a slope and about 300 feet apart. Parallel to the gangway, either above or below it, there is usually an airway driven about the same size as the gangway.

ARRANGEMENT OF BREASTS OFF THE GANGWAYS

21. Breasts are driven off the gangway and usually only on one side of the gangway, except when the gangway is located in the basin, in which case breasts may be driven on both sides of it. A number of ways of driving the breasts from the gangways are shown herewith.

Fig. 16 shows the breasts driven at right angles to the gangway and widened out inby. Pillar drawing has been

commenced at the end of the section of breasts, and the method differs in no way from the similar method for bituminous workings. This method is used where the seam does not dip more than from 3° to 5° or 6°, that is, up to the limit of mule haulage from the face. The drawing of the

FIG. 16

pillars has been begun and small stumps are shown as having been left in the gob, as it is not usually possible to draw the pillars as completely in anthracite as in bituminous workings.

Fig. 17 shows the breasts inclined to the gangway for the

FIG. 17

purpose of reducing the grade of the track in the breasts. Breasts driven directly off the gangway as shown in Figs. 16 and 17 and in which the grade is such that the mine cars can be pushed in by hand or hauled in by a mule are called **road breasts.**

Fig. 18 shows an arrangement of inclined breasts driven off the short diagonal gangways *a* known as *counter gangways.* This gangway is driven at such an angle to the main gangway as to give an easy grade for handling the cars by

mules or locomotives. The breasts are driven across the pitch as shown until they break through into each other.

FIG. 18

Fig. 19 shows a system of breasts driven on a full pitch with two chutes for each breast through which the coal is drawn from time to time, as will be explained in detail later.

FIG. 19

To give greater protection to the gangway, a pillar of coal *a* may be left at the lower end of each breast.

Fig. 20 shows two series or sets of breasts *a* driven at right

FIG. 20

angles to the gangway, the sets being separated by a wide reserve pillar *b* to afford greater security against a squeeze

or the sliding of the roof and consequent injury to the gangway. This method is adapted to heavy pitches or fragile roof, or both. These are chute breasts with a single loading chute for each breast, as was explained in detail in Art. **13.**

Fig. 21 shows the gangways *a* driven in the basin or syncline, the seam rising on each side. The method given is

FIG. 21

for working at a great depth where the coal is subjected to heavy pressure due to the coal dipping toward the basin from two directions. The breasts are driven in pairs, with a wide protecting pillar between the pairs.

METHODS OF WORKING BREASTS

22. For inclinations up to about 5°, breasts are driven at right angles to the gangways. For inclinations of from 5° to 10°, the breasts are driven at an angle with the gangway, or off from the counter-gangway, as shown in Fig. 18.

For inclinations of from 10° to 18°, that is, after mule haulage becomes impossible in the breast and before the inclination is such that the coal will slide on sheet iron, *buggy breasts* are used, as was illustrated in Figs. 6 and 7. Where the pitch is between 15° and 30° sheet-iron chutes are placed on the bottom of the breast and the coal is shoveled into these as illustrated in Fig. 8. Anthracite will slide on a flatter pitch than bituminous coal.

Fig. 22 shows a chute breast that is often used in anthracite mining. The seam of coal is inclined at an angle of about 20° and is represented as 8 or 10 feet thick, with a roof

above the coal that falls easily. The narrow place *a* called a chute is about 10 feet wide and 6 feet high and is driven the full length of the room. The top coal *b* is left up while the chute *a* is being driven to help support the roof. When the chute reaches its full length, the face is widened out to the desired width of breast and the coal is mined from the face *c* retreating

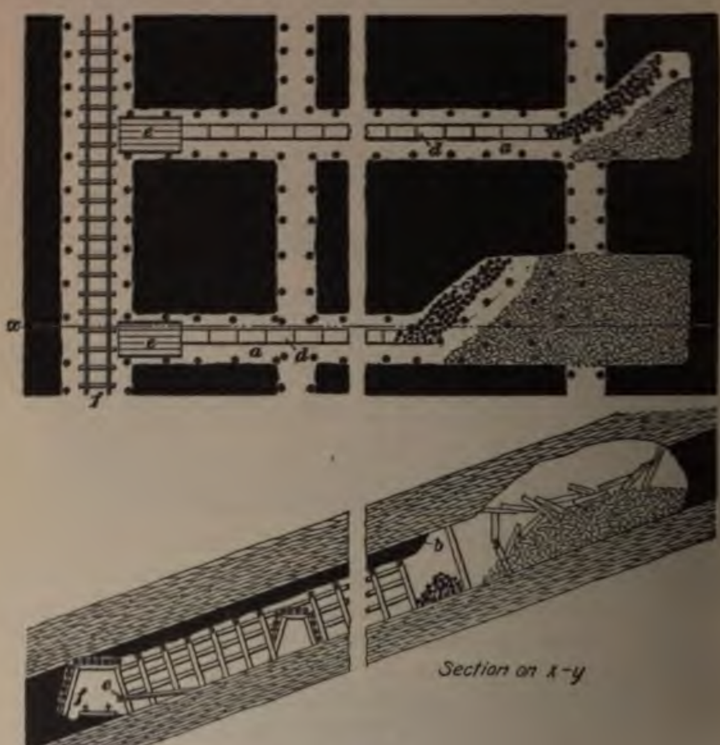


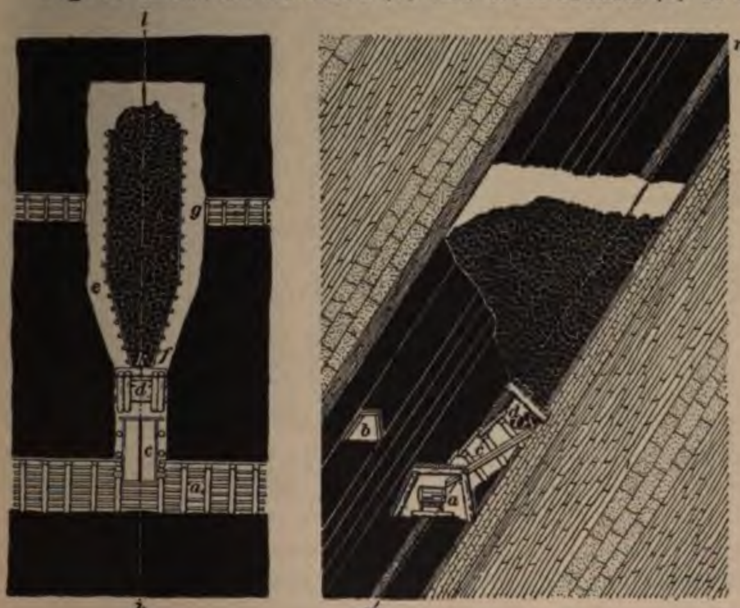
Fig. 22

toward the gangway. At the same time, the top is taken down across the whole room. A sheet-iron chute *d* is laid in the center of the narrow opening through the coal and into this the coal is shoveled as mined. At the bottom, it falls on the platform *e*, and from there it is shoveled into a car standing on the track *f*. After the top coal has been taken down, the room is allowed to fill up with gob as shown.

This method is particularly adapted to a thick seam with a weak roof.

23. Battery Breasts.—The methods of working by single and double chutes and batteries illustrated in Figs. 9, 10, 11, and 12 are adaptations of similar methods originally applied in connection with anthracite mining. Many modifications of these simple methods are used in order to meet the requirements of different pitches and different thicknesses of coal. The following are the most important of these modifications:

Fig. 23 shows an elevation (*a*) and cross-section (*b*) of a



(*a*) (*b*)

FIG. 23

breast in a thick seam pitching about 60°. The seam is 16 feet thick with several thin slate partings; the roof and floor are good, and the coal hard and firm. The gangway *a* is driven on the strike of the seam, near the bottom of the seam and with sufficient grade to insure drainage. A small airway *b* is driven just below the top bench of coal, and is connected

with the gangway by occasional openings not shown. This airway is often called a *monkey gangway*, or simply a *monkey*. A narrow opening called a chute is opened off the gangway and driven up on the floor of the seam a distance of about 5 yards, and at this point it is widened out gradually on both ribs, until the full width of the breast, 5 to 8 yards, is reached. A timbered chute *c* conveys the coal into the car on the gangway *a*. A battery of timber *d* is constructed at the point where the breast is widened out by setting double posts on each side of the center and close to the ribs; these posts are firmly set in holes cut in the floor and the roof, and cross-timbers are then placed behind them, leaving only a small opening for the coal to pass through. A manway *e* is constructed up each side of the chute, by placing about 30 inches from each rib a line of posts which are firmly set in holes cut in the roof and floor and lined with plank to form the sides of the chute. An opening *f* in the battery connects each manway with the chute *c* and also affords access to the face of the breast. Cross-cuts *g* are driven between adjoining breasts at points up the pitch. The breast is kept full of loose coal, on which the miner stands as he works at the face.

24. Fig. 24 represents in elevation and cross-section breasts driven to the full pitch of a thick seam whose inclination is about 60°. The gangway *g* is driven on the strike and in the top of the seam while the airway *c* is above the gangway and in the top coal.

The breasts are opened by a narrow opening 9 feet by 6 feet driven up the pitch for a distance of 18 to 24 feet, this neck being gradually widened out to the proper breast width, as shown. The section is taken on the lines *l k* and *i j*, and the elevation is made on the line *p q*, and does not show, therefore, the headings *c* and *d* shown in Fig. 24 (*b*). In the middle of the pillar between the loading chutes, a small manway *m* is driven up a few yards, and then branches *s s* are turned off in both directions until intersection is made with the breasts on each side. From these points the manways *w* are carried up on each side of the breast along the

rib as shown. A narrow manway *n* is usually made by planking off a portion of the opening so that the loaders may have free access to the battery at all times.

A small airway *d* is driven from airway *c* to the manway *m*, but cross-cuts between the airway and gangway are also necessary where much gas is given off during the working. The air current passes along the gangway *g* and returns along the faces of the breasts. The small airways *d* and *c* are not used when the breast is working, but if any acci-

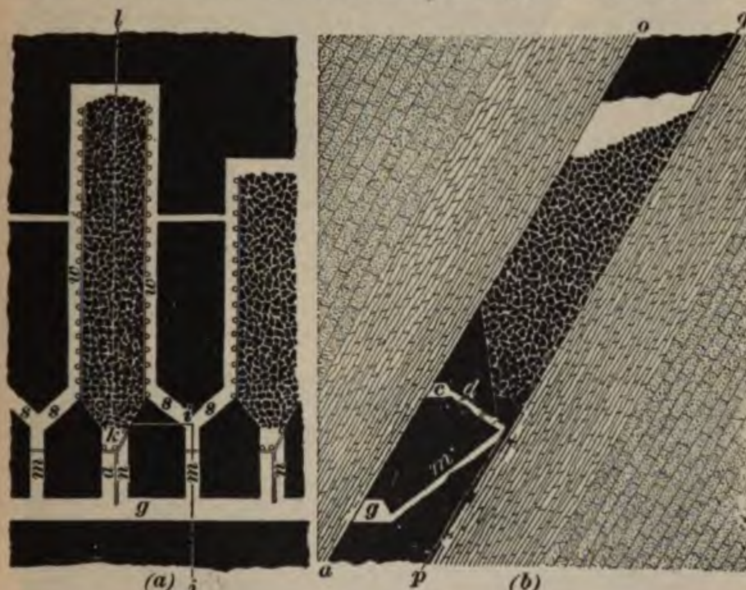


Fig. 24

dent takes place in a breast manway *w* by which the ventilation is blocked, the air can be conveyed around the breast through the airways *d* and *c* by simply removing stoppings. This plan is especially adapted to working thick steeply inclined seams of soft gaseous coal.

When the pitch of the bed is less than about 50°, the gangway *g* is usually in the bottom coal, but for a greater inclination it is in the top coal, so that the flow of the coal may be more easily controlled.

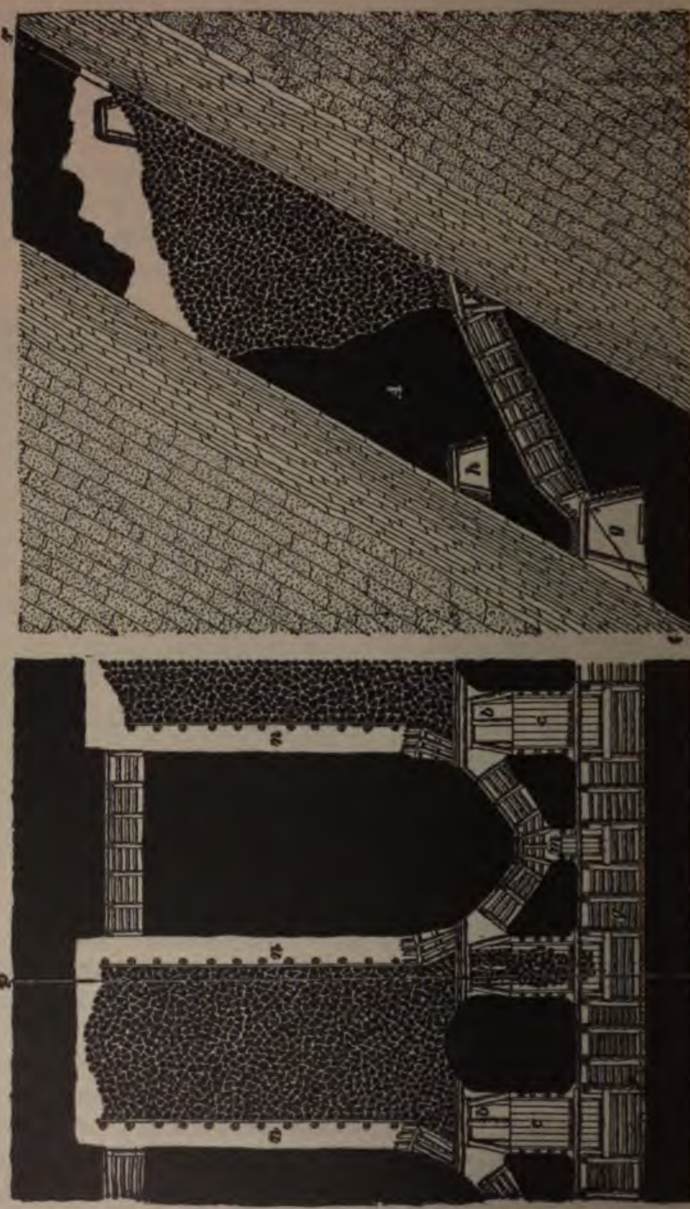


FIG. 23

25. Fig. 25 shows a method in which a loading chute *c* is arranged on each side of the breast and a supporting pillar of solid coal is left in the mouth of each breast; the batteries *b* are built near the upper side of this pillar. The gangway *g* and the airway *h* above it are driven in the top coal. The loading chutes *c* are driven up from the gangway and across the full width of the seam at such an angle that the coal can be easily controlled in the chute. When the chutes *c* reach the floor of the seam, they are widened out to breast width and at the same time the coal face is opened up to the top of the seam in a more or less vertical line, as shown in the cross-section, Fig. 25 (*b*). The manways *m* are driven through the gangway pillar between the breasts and are divided into two parts, as was described in connection with Fig. 24, a manway *n* extending up each side of the breast. The advantage of the method illustrated in Figs. 24 and 25 over that shown in Fig. 23 is that the manways and the coal chutes are kept apart and there is therefore usually free access to the face at all times, even should there be a break in the coal chute.

By driving the gangway near the roof, as shown in Fig. 25, where the pitch is heavy the loading chute *c* is more easily controlled, and the gangway is also less likely to be injured by a squeeze. The disadvantage of the method is the extra expense incurred in driving long chutes.

FIG. 26

26. Fig. 26 is a sectional view of a thick seam of coal standing vertically and mined by room and pillar. The gangway or level *g* is connected with the airway *h* by the passages *c*, *d*, and *e*. The battery *b* is at the inner end of the chute *c* and near the foot of the vertical manway *m*, in which a ladder is placed. The passages *d* and *e* are for the purpose of ventilation; they also serve as manways to connect the gangway *g* with the foot of the vertical manway *m*.

27. Fig. 27 is a section through what is called a *back breast* p in thick anthracite seams. The regular breast b having been mined out, the coal over the main gangway g and monkey gangway k is worked by opening a breast p off the monkey gangway or off another gangway driven especially for the purpose of getting out this coal, and driven so that the coal may slide through chutes to the cars. Such

FIG. 27

a mode of working may enable a large proportion of the gangway stumps to be removed, which would be entirely lost otherwise.

28. Difficulties in Mining on a Pitch.—A soft friable coal when mined on a steep pitch has a tendency to *run;* that is, without any mining, it breaks freely from the face of the breast and then slides down the pitch. Sometimes little or no work need be done in the breast after the chute has been widened out to form the breast, as sufficient coal thus breaks from the face from time to time to keep the breast full as the coal is drawn out through the loading chute; the coal continues to run until the breast breaks through into the

upper gangway. The uncertainty that necessarily exists in regard to the flow of the coal renders this method unreliable, although it is often adopted from necessity. One objection to this method is that the running of the coal cannot be controlled, and the widths of the breast and pillars cannot be maintained; the breast is often increased in width and much or all of the pillar coal runs out at the chutes, while at other times the width of the breast gradually decreases and ultimately the coal stops running. The miner must then go up into the breast and start the coal to running again by widening out the breast, or by placing one or more small shots in the coal; this is a dangerous operation, as the coal may come with a rush.

The coal on a steep pitch may not run sufficiently to do away with mining, but it may be so free as to require particular support at the face to prevent the coal from running sufficiently to injure the miners. The working of free coal on a heavy pitch requires skilled labor; and as gas usually issues from such coal in large quantities, safety lamps must often be used, thus increasing the danger from falls on account of insufficient light. The props used under these conditions should not be less than 6 inches in diameter and should be very firmly set. If the roof is strong and firm, these props may be taken out and moved forwards as required, thus saving labor and material.

In working coal by the battery method, the coal will sometimes become clogged and form an arch, which supports all the coal above the arch and allows the breast below to become empty as the coal is gradually drawn out through the loading chute. This condition is dangerous to the men working on top of the coal near the face, for if the arch suddenly gives away they may be carried down and buried in the coal. Such a slide is also apt to be very disastrous to the battery and the sides of the chute. To break down such an arch, an opening may be made in the side of the chute and the coal started to running by means of bars. Occasionally a small stick of dynamite is put under the coal and the arch loosened in this way. When this is done, an opening should be made from the side, and the miner should

not, as he sometimes does, climb up the chute and after setting off his fuse trust to getting out before the coal begins to slide, as this is extremely dangerous.

After the face has been blasted down, lumps of coal will sometimes lodge in the manways alongside the chute and

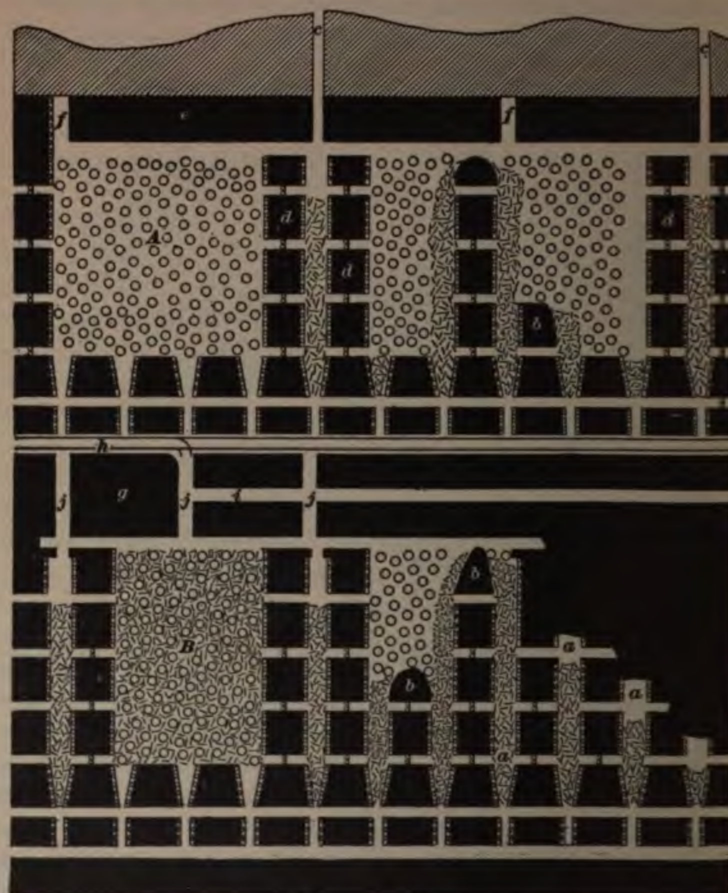


Fig. 28

these must be similarly dislodged by means of bars or with dynamite. In returning to the face after a blast, the miner should be exceedingly careful that the loose coal does not

roll down the manway on him, and should also use great care to see that all loose coal in the face is barred down before he again begins work.

29. Fig. 28 shows a method adopted by J. L. Williams at the Richards Mine, Mt. Carmel, Pennsylvania. The method is a modified pillar-and-stall one adapted to conditions where both the floor and the roof are weak. The rooms *a* are driven narrow and are protected by props closely set along the ribs, as shown. They are filled with the refuse made in mining, and, if that is not sufficient, rock is brought in from the surface. After the rooms have been driven up and filled with waste, the pillars are drawn back as shown at *b* and the whole space is filled with refuse. If the floor consists of clod, in order to prevent its lifting and sliding, every alternate prop is put through the clod and set on the slate underneath. The other props are then set on pieces of 2-inch plank about 2 feet long. An occasional room is pushed through to the surface, as shown at *c*, to form a chute through which timber is lowered, and, when necessary, rock for filling. These timber and rock chutes are protected by pillars *d*, which can be withdrawn after the necessity for the chute has passed. A chain pillar *e* is left above the upper tier of breasts just below the surface and this is taken out by means of cross-openings *f* if the coal near the surface is not too badly weathered. The chain pillar *g* between the gangway *h* and the next lower tier of breasts *B* is worked out by means of a small gangway *i*. Timber and refuse for the level *B* are lowered through the openings *j*. By this method, 90 per cent. of the available coal is said to have been taken out.

CONTIGUOUS SEAMS

30. Coal seams that are more or less parallel and are close together are said to be **contiguous**. The following points must be carefully considered in the working of contiguous seams: thickness and character of the material separating the seams; thickness of the seams; nature of the

roof, floor, and coal of each seam; inclination of the strata; the general depth below the surface.

Contiguous seams may be worked as one seam or separately.

31. Contiguous Seams Worked Together.—The thickness of strata separating contiguous seams varies from a fraction of an inch to several feet. When this thickness does not exceed 2 or 3 feet, the separating rock is called a *parting* and all the coal and rock are then usually taken out at the same time as one face of coal, or the face in the lower seam is kept a few yards in advance of that above. The waste material forming the parting is not removed in either case, but simply left where it falls, except on the roads, as the handling of so large an amount of waste would render the economical working of the coal impossible. At other times, the openings are first driven in the lower seam, and when these reach the limit of the workings the tracks in the rooms are taken up and the rock or slate parting is allowed to fall or is blasted down. The upper coal is then taken down.

32. Contiguous Seams Worked Separately.—Contiguous seams separated by a greater thickness than 3 or 4 feet of rock strata are generally worked separately, but there is no uniform rule as to the order of working such seams, much depending on the nature and thickness of the coal seams and of the intervening rock. In general, however, the removal of the coal in the upper seam first prevents the crushing of this coal, which is apt to result when the lower coal is removed first. If the lower seam is first developed, large pillars are left until the coal has been wholly taken out of the upper seam, after which the lower pillars are drawn. The pillars in the upper seam should be vertically above those in the lower. In room-and-pillar working, any subsidence of an upper seam due to the working out of a lower bed is a disadvantage in the working of the upper bed, even if the coal is not so crushed and broken by the subsidence as to prove unworkable.

Although the following methods of working contiguous seams are taken from anthracite practice, they apply equally well to bituminous mines worked under similar conditions.

33. Rock Chute Mining.—In the working of contiguous seams separated by a thickness of strata too great to permit of single working, it is often an advantage to convey the output of the overlying seam or seams to the surface through the openings driven in the lower seam, thus avoiding the driving and maintenance of separate haulage roads and slopes in each seam. Rock chutes are driven, as shown

FIG. 29

in Fig. 29, from the gangway *g* of the lower seam to the upper seam, at such a pitch that the coal will slide easily and without breaking from the upper to the lower gangway. The gangway *l* is then driven in the upper seam, and breasts are opened from it vertically over those in the seam below. The coal mined in the upper seam is transported through the gangways in the upper seam by mine cars or buggies, which dump the coal into the chute, which conveys it to the gangway in the lower seam, where it is loaded into the regular mine cars and conveyed to the surface. The maximum

thickness of rock strata through which it is economical to thus drive rock chutes depends on the character of the rock, the expense of driving the chutes, and the quality of the coal mined, which determines whether it will stand so much handling without excessive breakage.

34. Cross-Tunnels.—Another method of mining contiguous seams separated by a considerable thickness of rock

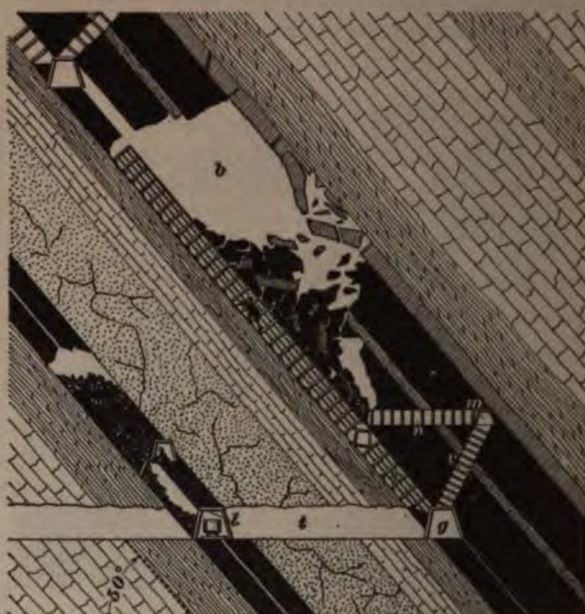


FIG. 30

strata, is to drive a cross-tunnel *t*, Fig. 30, through the rock from a gangway in one seam to intercept the other seams. The tunnel may be extended right and left to open seams above and below the thick seam. This tunnel is never driven under a breast in the upper seam but directly under the middle of the pillar.

In the upper and thicker seam, when the coal is very hard, a breast *b* is worked to the limit and the loose coal nearly all run out through the chute *s* into the gangway *g*. The monkey

gangway *m* is driven near the top as a return airway, and is connected to the upper end of the chute *s* by a level heading *n*, and to the main gangway *g* by a heading *v*. These headings are driven for the purpose of ventilation and to provide access to the battery in case the chute *s* should be closed. In the lower seam, the breast is being worked upwards in the ordinary manner.

MINING COAL AT THE FACE

35. General Considerations.—The problem that confronts the miner in mining coal at the face is, how can the largest amount of coal be safely mined in such size as will net him the largest returns for his labor, after deducting the necessary expense of powder, tools, oil, etc. The points to be considered in this connection are: the safety of the workmen; a close adherence to the system adopted for working the mine; a maximum output in the best possible marketable condition both in regard to size and purity; minimum expense for powder, tools, etc.

To accomplish the best results, the miner must depend as much or more on the natural forces and conditions under his control as he does on blasting. The roof pressure, the pressure of gas occluded in the coal, or confined in the cracks or crevices of the seam or of the underlying or overlying strata, and the cleat of the coal that causes it to break more easily in certain directions may be of great assistance to the miner.

36. Effect of Roof Pressure.—The pressure of the overlying strata on the coal face, if properly controlled by the timbering, and the method of working may be more effective in breaking the coal than powder. A suitable direction of the working face with reference to the inclination of the seam, or the cleat of the coal, and a uniform line of face in a single room or in a series of rooms often enables the roof pressure to be utilized in doing much of the work of breaking down the coal. Owing to the steady advance of the working face, a continual state of unrest is maintained in

the overlying strata; this is sometimes called the *traveling weight*, and if controlled by the method of working and timbering at the face it is most helpful in the breaking of the coal. The timbering should be so placed as to throw this weight on the face of the coal to such an extent as experience proves to be most beneficial for breaking the coal without crushing the face.

The length of face that will give the best results depends on several factors. In machine mining it is important to have as great a length of continuous face as possible, in order to save the time consumed in moving the machine from one place to another. Again, some long-grained coals give more lump coal as the length of the face is increased; on this account, panel breasts are preferable in mining such coal. The nature of the roof or floor, or both, often limits the length of face, however, to the width of a single room or chamber, and to avoid excessive weight on the coal this may have to be made narrow. In general, however, the greater the length of continuous working face, the more effective is the roof pressure in breaking down the coal. The control of the roof pressure is, therefore, of more importance in long-wall mining than in room and pillar.

CUTTING THE COAL

37. Undercutting (Bearing-In, Mining, Holing, Kerving).—In order to take advantage of the roof pressure at the face, it is necessary to properly undercut the coal. This undercutting consists of cutting away with a pick or mining machine the lower portion of the coal seam as shown in Fig. 31, or of the underclay (thill), forming the floor of the seam, Fig. 32. When the coal is undercut by hand the miner lies on his side when undercutting, and in order to prevent the coal, above him from falling, short posts, called *sprags*, are placed under the edge of the coal, as shown at *a*, Fig. 31, or else a *cockermeg* is placed against the face, as shown in Fig. 32. As the coal is undermined, it settles on these sprags, and when it is desired to load out the coal the

Fig. 91

sprags are knocked out and the coal either falls by its own weight, or it is wedged or blasted down.

The fine coal or slack produced by the undercutting is usually loaded into the mine cars together with the lump coal. When the mining is done in the underclay, the clay is shoveled back into the gob if there is room for it. Sometimes this underclay is suitable for the manufacture of brick, and it is then often taken to the surface and used for that purpose, thereby increasing the profit from mining the coal. The clay in which the mining is done is sometimes called the *mining dirt*.

Water in the fireclay in small amounts usually renders mining easier, but larger quantities make it necessary to dig small sumps for its reception, and it is then a hindrance to mining.

38. The height of the front end of an undercut should be as small as it is convenient for the miner to work under, and it varies from 10 inches to 2 feet, depending on the depth of the undercut and the breadth of the miner's shoulders, for if

FIG. 32

the cut is deep, so that the miner must be under the coal, as shown in Fig. 32, he must have sufficient room to square his shoulders if he is to work to advantage.

The depth of the undercut depends mainly on the thickness of the seam. A moderately thick seam (not over 6 to 7 feet) is generally undercut to a depth equal to its thickness, and such an undercut can generally be put in before the weight comes on the coal; in very thick coal beds, however, this rule can seldom be followed as the weight comes on the coal before the entire face is undermined; mining in benches is

then necessary, that is, the seam is mined in sections, as if it were made up of several contiguous seams with small partings between, advantage being taken of the partings as places where the coal can be separated. The depth of mining is also affected by the ease with which the coal parts from the roof, as a coal seam that separates easily from the roof is not undercut as deep as one that does not separate easily.

39. While it is generally clearly understood that the roof pressure is often used to break down the coal, it is not as generally understood that this same roof pressure, if given time to act on the coal being undercut, will greatly assist the work of undercutting, since the crushing action of the roof pressure on the coal makes the coal at the face of the cutting more brittle and easier to mine. It is better, therefore, not to undercut the full depth at once but to start a shallow cut in the clay seam or in the lower coal and carry it the entire width of the coal face. While this is being done, the roof pressure has an opportunity to act and by the time the miner returns to the side of the room at which he started, he finds the coal in the back part of the cut more tender and easier to mine than before. He now carries a second shallow cut across the face of the room, and so on with other shallow cuts until the full depth of the undercut is reached, giving opportunity for the roof pressure to act between each mining. The advantage derived from a number of shallow minings depends on the nature of the coal and roof. The effect is to throw the roof pressure on the coal face gradually and to break the coal in larger pieces.

40. Mining in Center or Top of Seam.—When bands or balls of pyrites occur in the bottom coal or underclay, it is usually impossible to place the undercut in it, and the presence of pyrites in quantity in a certain part of the seam often prevents the use of mining machines, or even mining by hand in that part. Recourse must then be had to shooting off the solid or to mining at a higher point in the seam. A band of clay, bone, or soft coal, lying in the center or

at the top of the seam often presents a better point for a bearing-in cut than the bottom; and when conditions are favorable such places are used, especially in hand mining.

Fig. 33 represents a section of a room at the face, where the mining is done in a thin stratum of soft clay at the middle of the seam. When the cut is completed, the upper bench of coal may fall with the knocking out of the sprags, or it may have to be wedged down with iron wedges driven between the top of the coal and the roof, or possibly blasted down with light shots.

The slate partings may be taken down before this work is done, or may be separated from the coal after the latter is broken down, as proves of the most advantage. The lower bench of coal is then lifted by wedges, or by means of a light lifting shot placed in the floor. The two benches of coal are sometimes of such different quality and market value as to require being loaded separately. The value of the coal in this respect should be carefully ascertained and the benches worked accordingly.

FIG. 33

Some mining machines make a cut only 4 inches in height. This does not give sufficient height to break the top coal in a thick seam with several partings. It is better to wedge down the lower bench of coal first, spragging the upper benches meantime. After the bottom coal has been removed, the sprags are knocked out and the upper benches allowed to fall, or are wedged down singly or together as desired.

41. Shearing.—A shear is a vertical cut made from top to bottom in a coal seam. It is usually made at the side of the face, as shown in Fig. 34, and is then often called a *side cut*. A shear is occasionally put in the center of a face. A side cut, or shear, differs from an undercut only in being

vertical and is made the same depth and width as an undercut. The purpose of shearing is to give an additional free face in blasting, so that the same work may be done with less powder. Shearing and undercutting are often called *holing*. As a general rule, the work expended in holing is repaid by the increased quantity of coal broken down by a given blast; there is a proportionate saving in the powder used per ton of output, and the quantity of small coal produced is less. With a narrow place undercut and sheared as shown, a single shot placed at *a* and inclined slightly upwards should bring down the block of coal if it does not fall of its own weight or by wedging. Shearing may be done either by hand or by means of coal-cutting machines.

Fig. 34

42. A method of shearing known as *following the crack*, consists in shearing to a depth of 2 feet, and firing a shot called a *snubber*, placed close to the side of the cut, the hole being drilled 3 feet deep, thereby locating the charge 1 foot on the solid. The firing of the snubber cracks or crevices the seam along the rib. After the firing of the snubber, successive back shots are fired between these and the rib at the far side of the face, the coal being removed after the firing of each shot. The next shear or side cut is made at the place where the snubber, drilled 1 foot on the solid, has cracked the coal. The particular advantage of this method is due to the jagged line of the rib produced by the successive shearings and snubber shots, resulting in less liability of the roof to crack along the rib, so often manifest in a straight rib.

BRINGING DOWN THE COAL

43. If the coal has been merely undercut, or undercut and sheared on one or both ribs, it often falls by its own weight. If it does not fall by its own weight, it is easily brought down by driving steel wedges, Fig. 35, between the top of the coal and the roof, or into a soft streak in the seam. These wedges are made of cast tool steel and weigh from 1½ to 5 pounds. Instead of being wedged, the coal may be broken down by a single light shot placed near the roof and in the center of the face. It is very unusual, at present, for a miner in America to both undercut and shear his coal, as it is very much less laborious to either undercut or shear and to do the rest of the work by blasting or wedging or even to depend entirely on blasting. This is not always good practice, however, for while the miner may save some time by not undercutting first, or by not shearing after he has undercut, if he depends so largely on the powder to bring down the coal, his output is decreased, the coal is not obtained in as marketable a form as when properly undercut and sheared, and the cost for powder is greatly increased. Shearing on either rib, or on both ribs, after the coal has been undermined, is done in some localities where the coal would be too much shattered by the use of powder and this practice could with advantage and economy be much more widely followed than it is at present, even in districts where it is not a necessity on account of the character of the coal.

FIG. 35

Where the coal is sheared, it is often not undermined; but, using the shear or cut as an open end, the coal is blasted to right and to left of the cut, if in the center, or from one side if cut on the rib.

44. Narrow Work.—Fig. 36 shows an ordinary method of shearing and blasting as used in narrow or entry work. A shearing is made in the center of the face, which rounds off the left side of the coal as shown and gives the block of coal

abcd two free faces *ab* and *ad*. A drill hole is placed, as shown, about 10 inches from the rib *cd* and of such depth that the point of the hole is on a line with the point of the shearing. The hole is located about midway in the face vertically and is inclined upwards at an angle of about 10° and usually also toward the line of the rib. A shot placed in the hole should take out the block *abcd*, and another shot similarly placed near the left rib, but somewhat deeper, should

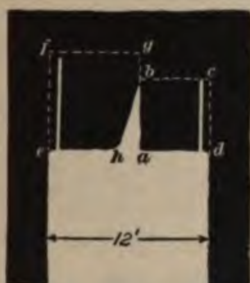


FIG. 36

FIG. 37

take out the block *efgh*. The face is then ready for another cutting. The line *fg* may be in line with *bc*, or it may be slightly in advance of it, as shown, if the left-hand shot is thoroughly effective.

Fig. 37 shows a method of placing the shots in an entry that has been cut along the rib instead of in the center.

45. Wide Work.—In a wide entry or a room mined out

(a) FIG. 38 (b)

by a combination of shearing and blasting, the cut may be placed in the center and the shots arranged about as shown in plan in Fig. 38 (*a*) and in elevation in (*b*), the dimensions and

arrangement given being approximations, since absolute positions and figures that will apply to all cases cannot be stated.

If the coal has an end cleat, the cut should be made along the rib; and if this end cleat is more pronounced on one rib than the other, the cutting should be done along that rib. When the cleat is present, the rib shots should be placed far enough away from the rib (at least 1 foot) so that the shot will not cut into the rib.

46. Mining Pick.—The general form of the miner's pick, Fig. 39, is straight and slim, having a uniform taper from the center of the shank to the bit. The weight of the pick varies from 1½ to 8 pounds, but the usual weight for mining ordinary bituminous coal is from 2 to 3 pounds. This weight is without the handle, which is made detachable, so that the same handle answers for a number of picks, thus greatly reducing the weight of tools to be carried in and out of the mine daily. The pick is made in different lengths, adapted to different coals and different kinds of work. The bit shown in Fig. 39 is drawn out to a slim point adapted to coals of moderate hardness. The bit shown in Fig. 40 has a blunt point, and is adapted to harder coals. For exceedingly hard coal, the poll pick shown in Fig. 41 is sometimes used.

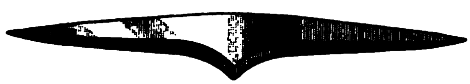


FIG. 39

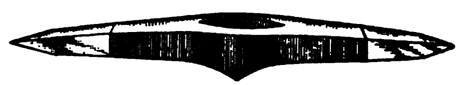


FIG. 40

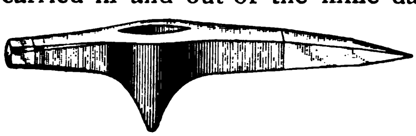


FIG. 41

47. In **tempering** the bit of a mining pick, the temper should not be drawn too high or the point of the pick will be too brittle. Fig. 42 shows the series of colors in the order in which they flow down the bit toward the point of the pick. In a good quality of pick steel, these colors stand out plainer than in steel of a lower grade, and for this reason the

strength of the colors is a good indication to an experienced blacksmith of the quality of steel he is working. In tempering a pick, the shank of the pick being so much heavier than the points or bit, great care is required in heating that the point be not burned. Where the pick does not require much sharpening of its point, it is often better to heat the shank of the pick hotter above its point and let the heat draw down to the point after taking the pick from the fire. If the same degree of heat is applied throughout, the point of the bit is almost sure to be burned. The shank may be heated by running the pick into the fire so that its point extends somewhat beyond the hottest portion of the fire. Assuming that the point has been shaped, if the heat in the shank is still sufficient for drawing the temper, the bit is quickly cleaned of any adhering cinder and the colors then watched as they flow down toward the point until the purple-brown, or the purple or deep blue reaches the point, when the bit is plunged at once into water, moving the same about to prevent a line of fracture forming in the steel at the surface of the water. In ordinary mining work, the temper of the pick should be drawn at a deep blue, but when a higher temper is required, the cooling may be done when the point is a purplish-brown.

FIG. 42

FIG. 43

48. Use of the Pick.—The miner should be able to use the pick either right-handed or left-handed, for, in the limited

space afforded in mine workings, he will frequently have to work either way. In Figs. 31 and 44, the miner is represented as working right-handed; and in Figs. 32 and 43, left-handed. Experience teaches a miner how to cut different coals and how to hold and handle his pick so that coal will not fly in his face when he works. In undercutting, the stroke of the pick is in the plane of the stratification, hence the pick tends to become wedged; this should be avoided as far as possible by using a light pick and delivering light blows. The work of undercutting should be commenced at the bottom and proceed upwards, for when the bottom layer has been cut out, the upper layers are more readily brought down.

FIG. 44

In shearing, the cut or shear should be started low and progressed upwards, as illustrated in Fig. 43. While this is the common method of shearing, it is not always the best method, as some bituminous coal has a peculiar, soft, fibrous texture and is bedded in foliated layers that are better cut from the top downwards, as shown in Fig. 44.

SHOOTING OFF THE SOLID

49. The term **shooting off the solid** is used to describe a method of working in which the coal is blasted from a solid face without previous undercutting or shearing. It is the only method used in mining anthracite, and is also much used in bituminous mines. The chief labor in production of coal by this method is the drilling of the holes for the powder

and the loading of the coal into mine cars. The holes are drilled with a churn drill or with a rotary drill worked either by hand or by electric or compressed-air power.

The location of the holes, the depth to which they must be drilled, and their direction depend on the nature of the coal. If the coal is compact and without cleat, as is the case with anthracite, the holes are placed as they would be for a rock face worked under similar conditions. If the coal has a cleat, advantage must be taken of this to produce the maximum effect of the shot and to prevent the shot seaming out. The best method of blasting a particular coal can only be learned by experience.

The general methods of charging holes and firing the charge is fully described in *Explosives and Blasting*, but the following details apply especially to the blasting of coal. Only a few of the many arrangements of holes can be given.

50. Fig. 45 shows a common method of placing the shots

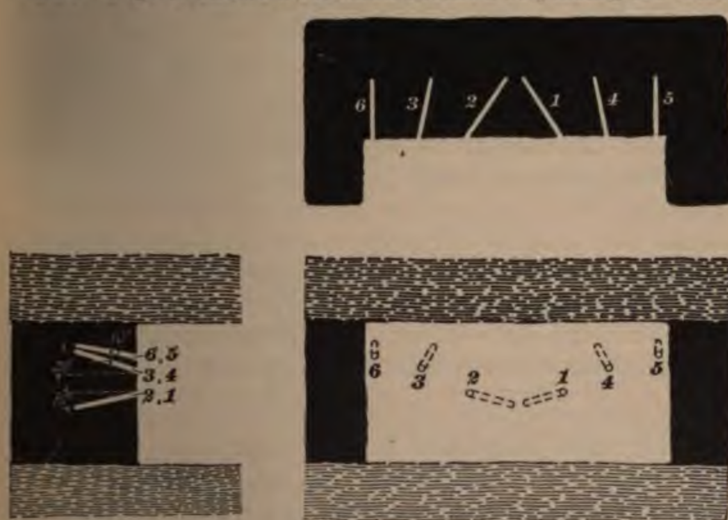


FIG. 45

in shooting off the solid used both for rooms and wide entries, where the coal is 5 to 7 feet thick and is strong and close-grained and without cleats or partings which need be

considered in the blasting. The holes are fired in the order of the numbers given and are put in at about the angle indicated. Shots *1* and *2* are sometimes called ***breaking***, or ***busting, shots***, as they break out the center and thus give loose ends for the shots *3* and *4*, which should take out the greater part of the coal. The shots *5* and *6* are placed about 10 inches from the ribs and are intended mainly to straighten the ribs, they are often inclined toward the rib. A cut from 4½ to 6 feet deep across the face should be taken out by such a round of holes.

If any shot does not blow out the entire face from top to bottom, it is necessary to mine out the bottom or top coal that is left in order to square up the face in preparation for the next round of shots. Occasionally, a short hole, or ***plug shot***, is used to do this, but such a shot results in small coal, and a pick should preferably be used. The miner aims to keep the center slightly ahead of the sides in order to have free faces for the side shots. The only difference in the application of this method of placing the shots for a room or entry is that the shots are closer together in the case of an entry.

51. In shooting fairly hard bituminous coals, especially where the coal breaks in wedge-shaped pieces, the holes should be inclined at a small angle with the face of the coal. Shots inclined to the face of the coal are called *grip shots*, and the shot is said to be *gripped* more or less according as it makes a greater or less angle with the face. When a shot is gripped too strongly, and the charge is located too deep on the solid, the force of the blast will be insufficient for the strength of the coal and may result in a blown-out shot.

52. If the center of the coal seam is soft or if it contains a parting, shots placed near the center, as shown in Fig. 45, may only tear out a gap, leaving the top and bottom intact. Under such conditions, it is necessary to place the shots so as to blast off the top and bottom alternately, as is shown in Fig. 46 (*a*), (*b*), and (*c*). The holes are placed across the face about as shown in Fig. 45, but are inclined at a much greater angle with the horizontal. In Fig. 46 (*a*), the coal

face is shown vertical and the first round of drill holes is intended to take off the lower part of the face; the holes are run from a little below the center of the coal as shown at *1*, Fig. 46 (*a*), and, excepting the buster and rib shots, the holes are drilled diagonally across the face of the room and downwards, so that the charge of powder is placed across the strong portion of the coal to be displaced. This round of shots will throw out the bottom coal and leave the coal face standing with the top overhanging as shown in Fig. 46 (*b*).

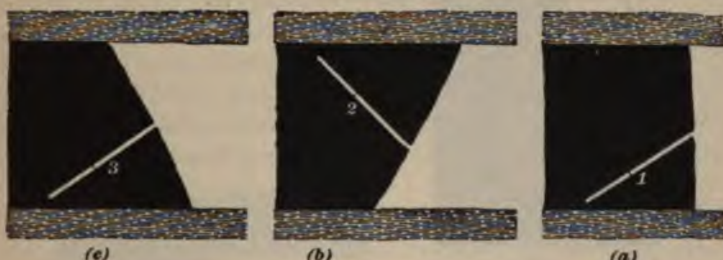


FIG. 46

The next round of holes *2* is run upwards and diagonally across the room to take off the upper bench of coal. The third round *3*, Fig. 46 (*c*), will be run downwards, and by thus alternately inclining the rounds upwards and downwards the face is advanced.

53. If the face is kept straight and center or buster shots must be used in connection with each round, an excessive use of powder is necessary and a larger amount of small coal is made than where an irregular face is carried, with the center in advance of the sides, or with either side in advance of the center. An irregular face provides a free side for the shots and allows the holes to be placed to greater advantage than where the face is kept straight. Fig. 47 shows a method of blasting off the solid that is applicable either to rooms or to wide entries under conditions similar to those given in connection with the method illustrated in Fig. 45. The coal is assumed to be from 5 to 7 feet thick, strong and close grained, and without partings or cleats that interfere with or

assist in the blasting, and is under a strong roof. Fig. 47 (*a*) and (*b*) shows the location of the holes in the first round. These holes are placed about midway of the face vertically; they are inclined to the face about as shown in view (*a*) and to the horizontal about as shown in view (*b*). Shot *1* is a buster shot, which takes out a piece *a*, *b*, *c*; shot *2* is placed about 10 inches from the rib to straighten the rib; shot *3* takes out the greater part of the center coal, while *4* and *5* act similarly to *1* and *2*. After the straight face has thus been broken, the location of the subsequent shots is

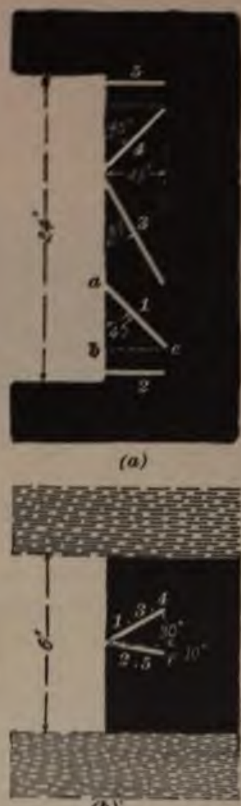


Fig. 47

Fig. 48

largely a matter of judgment, as so much depends on the conditions. No definite rules can be given, excepting that in solid coal the direction of the hole should be parallel to a free face if possible, though even this general rule will be greatly modified by cleats, partings, etc.

Fig. 48 shows approximately the appearance of the face after the shots shown in Fig. 47 have been fired. If there

was a cleavage to the coal, a shot placed about as shown might blow out the piece of coal within the dotted line and thus provide two free faces with respect to which side shots could then be placed. If there was no cleavage and the coal was hard and solid, the shot would be placed nearer the previous shot *4*.

54. Advantages and Disadvantages of Shooting Off the Solid.—Successful solid shooting requires a fairly strong roof and one that does not easily break if the timbers are displaced by blasting, as frequently occurs. If too much coal is broken by a shot and thrown about the room, props are knocked down, thus weakening the roof. An advantage of keeping the center or one side of the face ahead is that coal is then thrown to the side and not at right angles to the face and back on the props.

Solid shooting is economical where powder is comparatively cheap. The method is much used at small mines that cannot afford an equipment of machines for undercutting and shearing, but it usually requires an excess of timber on account of the amount lost by the blasting. There is also an increased liability to accident from excessive use of powder, and the ventilation of the mine is also interfered with unless all the shooting is done at one time. The practice of shooting off the solid is often carried to a dangerous extent by drilling deep holes that may be heavily charged with powder, and by not giving the shot sufficient opportunity to work or free itself. Shooting off the solid produces an excessive amount of small coal and slack, especially where it is carried on by the use of unnecessarily large charges of powder, and by unskilled miners.

BENCH MINING

55. The term **bench mining** refers to the mining of thick seams that are usually composed of two or more benches or separate layers of coal, separated by clay, slate, or rock partings of varying thicknesses. The benches of coal composing the seam are often of quite different quality and

FIG. 49

value and it is sometimes necessary to separate these several benches in their mining. When there is a great difference in the value of the coal in the different benches, only the best coal is taken out at first, the poorer benches being left for a subsequent working; or they are abandoned, but in this way a large amount of coal is lost. In working thick seams by benches, the order of working may be from top down or from bottom up. In working the lowest bench first, the work of mining is commenced by mining out the underclay, if such is present, and wedging or blowing down the bottom coal. The upper benches are then wedged and blasted down in order, an effort being made to bring down the coal and the refuse in the partings separately, so that the refuse will not become mixed with the coal. A bench of soft coal that would be too much broken by blasting may often be preserved by the removal of the lower benches first, after which this bench is allowed to fall or is wedged down.

If no underclay is present and the bottom coal is hard, a convenient place for the bearing-in may be found in some of the softer and poorer qualities of coal, or in the partings of the seam; the upper or lower benches may then be taken out as conditions may determine. When the several benches are worked quite separately, the upper bench may be worked first, the face of the upper bench being kept several yards ahead of the lower, as shown in Fig. 49. If, however, the lower benches are kept in advance of the upper ones, advantage is taken of gravity in bringing down the upper benches. At times, the bottom coal breaks better by wedging it up from the bottom than by shooting, making it preferable to keep the upper benches in advance and to wedge the lower coal. The conditions in coal mines are so variable that the miner must be guided by his judgment and experience as to the order of working the benches. If the top bench of coal is firm and easy to keep up, it is often of great advantage to leave this coal up until the other benches have been mined out, so as to insure a good roof while the other benches are being worked. This top or roof coal is then taken down after the rooms are worked out, or sometimes when the pillars are drawn back.

OBSTRUCTIONS TO WORK AT THE FACE

56. Draw Slate or Following Stone.—Immediately overlying the coal seam, there is frequently what miners term a **draw slate, stone,** or **following stone.** This is a stone varying from 8 to 20 inches in thickness, is of a dull color and a heavy texture, and as it breaks across the bedding quite readily it often falls with the coal. Such a top gives a large amount of dirt to be handled, as it breaks over props in room-and-pillar working and sometimes it must be taken down by the miner before he can set his props. The draw slate can often be held up better by working the rooms across the face of the cleat. In entry work in a thin seam, the draw slate may be an advantage, as it is easily taken down to provide the necessary headroom.

The **clod,** which is often found near the roof of a coal seam, is a tough carbonaceous shale or clay that is similar to draw slate but more difficult to separate from the coal, and is not as uniform and regular in occurrence as draw slate. Both draw slate and clod are useful in building stoppings.

Sulphur balls (iron pyrites) may greatly increase the annoyance and expense of mining, for if they occur in the bottom coal or in the underclay they often render mining with a chain machine impracticable. In hand pick work and with the pick machine, it is possible to mine around these obstructions. Iron pyrites frequently occur in thin layers interstratified with the coal; and unless these layers of pyrite are separated from the coal the market value of the coal may be considerably reduced. The coal is sometimes split and the layers of pyrite taken out and thrown in the gob, but it is bad practice to throw this into the gob, especially if much fine coal is present, since the pyrite may assist in starting spontaneous combustion in the gob.

57. Approaching Abandoned Workings.—When the working face is being driven in the direction of abandoned workings, extra precaution is needed to guard against a

sudden outburst of accumulated water or gas, or both. The accumulation of water in the abandoned working is often under a considerable head, owing to the height to which the water has risen in the shaft or upper portion of such workings. The pressure on each square foot of the coal at the face is equal to the weight of 1 cubic foot of water (62.5 pounds) multiplied by the vertical head of the water, in feet. For example, a breast opening 25 feet wide driven in a 5-foot seam, has a sectional area of $5 \times 25 = 125$ square feet. If the head of water in the abandoned workings is 150 feet, the pressure due to this head is $62.5 \times 150 = 9{,}375$ pounds per square foot, and the total pressure distributed over the face of the breast opening is, then, $\frac{9{,}375 \times 125}{2{,}000} = 586$ tons, nearly. The danger arising from this enormous pressure exerted on the face of the coal in a barrier pillar may easily be realized.

FIG. 50

In approaching abandoned workings, drill holes should be kept in advance of the working face as shown in Fig. 50, to give timely warning of the danger. The Bituminous Mine Law of Pennsylvania specifies that bore holes shall be kept not less than 12 feet in advance of the face and on the sides of such working places; these side holes should be drilled diagonally not more than 8 feet apart; the law also limits the width of the working place to 10 feet. The Anthracite Mine Law of Pennsylvania limits the width of a working place approaching abandoned workings liable to contain accumulations of water to 12 feet, and provides that drill holes shall be kept at least 20 feet in advance of the face, one drill hole being at the center of the working, and flank holes on each side.

Fig. 50 represents a pair of entries being driven toward abandoned workings. For the greater protection of the

workmen and the mine, one of these entries has been temporarily abandoned, and the other entry advanced with drill holes bored in the face and sides, as shown. The flank holes make an angle of about 25° or 30° with the ribs, the length of each hole being not less than 20 feet. A line of brattice is carried forwards from the last break-through toward the face of the entry, so as to compel the ventilating current to pass around the face. Safety lamps are used while doing this work, and a careful watch is kept at the floor and roof of the seam for the first appearance of either gas or water. Plugs are kept in readiness for instant use in case a sudden flow of water is encountered. When such an entry is driven forwards for the purpose of tapping the water known to have accumulated in the old workings under a considerable head, all the men should be notified and withdrawn from the mine previous to the tapping of the water.

METHODS OF WORKING

(PART 3)

LONG-WALL METHODS

INTRODUCTION

1. Definitions and General Principles.—The **long-wall method** of mining coal, as the name indicates, consists in arranging and maintaining a more or less continuous line of breast or working face. Its characteristic features, and those that distinguish it from other methods, are the complete removal of the coal in the first working and the fact that the roof is allowed to sink as the workings advance. The coal is usually removed without blasting, being undermined and then broken by the roof pressure.

2. Fig. 1 represents, in outline, the general plan of the long-wall face, which, as shown, is advanced in sections, each section being practically an arc of a circle. From the shaft, or point from which the workings are opened out, a number of roads are kept open for haulage purposes to the working face, as shown. Roads *a*, *d*, *e*, *h*, and *i* are called **main roads, or main entries,** as they are kept open permanently. The roads *d* and *e* are sometimes called **diagonal main roads, or main diagonal roads,** as they cut diagonally across the workings between the straight roads *a* and *h* and *a* and *i*.

Each of the broken straight lines represents a temporary road from the face to the nearest haulage road. The distance

between any two of these broken lines constitutes a **working place,** or a **room.**

The **cross-roads** *b*, *c*, *f*, *g*, *j*, *k* are driven off the main roads usually at an angle of about 45°, and their purpose is to cut off the working rooms from time to time so that the haulage distances may be reduced. The distance between cross-entries, or the limiting lengths, of the rooms is determined

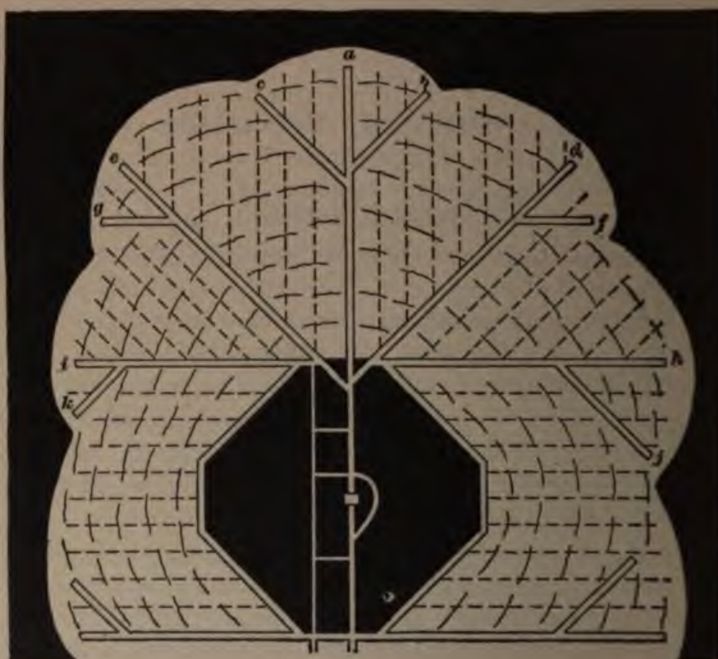


FIG. 1

by the time it is possible to keep the **temporary roads** from the face to the main or cross-roads open.

The waste material from the seam, roof, or floor, is built in the form of **pack walls** along each side of the roadways and in the spaces between, from which the coal has been taken out. The pack walls, or packs, lining the roadways, are called **road packs,** and those between the roads **gob packs.**

3. Fig. 2 shows a detail of the face of a long-wall room, or working place, in which *a* is a main road off which the temporary road *b* to the face is driven at a right angle instead of at 45° as shown in Fig. 1; *c c* are the road packs along the main road, and *d* the packs along the temporary road *b*. The face is protected by two lines of props and a road *e* runs along the face and out through *b* to the main road *a*. The roof is shown as having settled down on the packs and as breaking down over the gob back of the packs.

FIG. 2

4. Roof Settlement.—The removal of the coal and the slow advance of the working face is followed by a slow, but irresistible, downward movement of the cover or overburden, known as **settlement.** The immediate effect of this movement is to produce breaks or cracks in the roof strata over the area from which the coal has been taken, more or less parallel to the working face, and at right angles to the line of advance, as shown by the irregular broken lines in Fig. 1, and also by the cracks shown in Fig. 3. The settlement of the roof after the coal has been taken out brings a weight, or pressure, on the coal face, and the success of long-wall

work depends largely on whether this weight can be controlled and directed by the use of timbers and other methods of supporting the top. When thus controlled, it forms the most important element in breaking down the coal after the face has been undercut, so that the coal is brought down almost entirely without the use of explosives. The gradual settlement of the roof compresses the gob packs back from the face, as shown in Fig. 3, while the roof often breaks and the spaces from which the coal has been taken are then filled with the broken roof rock, which then assists the packs in supporting the overlying rock.

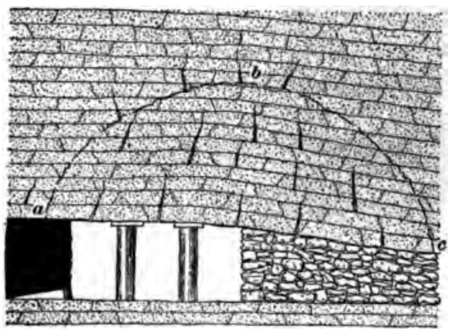


FIG. 3

5. Control of Roof Pressure.—The aim in long-wall work is to so control the roof pressure that it may be just sufficient to break the coal from the face and yet not crush it. When this pressure can be controlled, it is done by means of the number and size of the pack walls, by rows of props placed parallel to the face, and by varying the open space left along the face between the coal and the pack walls. Experience under the given conditions alone determines in just what way and to what extent this control may be secured. The pack walls provide for a gradual and uniform settlement of the roof over the entire area from which the coal has been removed. They relieve the timbers at the face of a great part of the weight they would otherwise have to carry and permit the weight on the coal face to be regulated largely by means of timbers so that the coal may be properly broken and not crushed.

6. An attempt is made in Fig. 3 to show the conditions, as far as they are known, of the roof strata above

the long-wall face after the coal has been removed. The effect of removing the coal is to divide the overburden into two portions:

1. An *overarching weight* due to the weight of the entire overburden above the line *a b c*. This weight is irresistible, and its effect is to compress the pack walls and gob into spaces between the walls until the resistance offered to the weight is practically equal to that of the coal that has been removed. The amount of settlement due to this overweight is regulated mainly by the proportion of pack walls to the entire area from which the coal has been removed and by the manner of building these pack walls.

2. An *underweight* of fractured material below the line *a b c*. The weight of this broken material is small, compared with the overweight, and it may be temporarily supported by the timbers and by the face of the coal and the packs. By the withdrawal of the timber next the packs, the weight is thrown, or settles, forwards on the coal and breaks it. The amount of the underweight thrown on the coal face is controlled, as far as possible, by the posts set parallel to the face. The amount of timber, number of rows, and the distances apart of the rows and of the timbers in each row depend on the conditions at the face. For given conditions of roof and floor, more weight is thrown on the face of the coal by decreasing the amount of timber, while increasing the timber decreases the weight on the coal.

With a hard roof and floor, the posts should be set on some soft material, or be provided with a thick soft cap that will yield and allow the post to take the weight gradually, or the post is sometimes tapered at the end for the same purpose.

7. Excessive weight on the face of the coal is shown by increased hardness of the under clay and the increased difficulty of undercutting in it, and also by the crushing and nipping of the coal. This excessive weight may be due to too small packs and too little timbering, or to the attempt to carry too wide an area between the packs and the face.

The remedy is to increase the amount of timber and the size or number of packs, or to decrease the distance between the face and the packs.

Too small a weight on the face of the coal is evidenced by the slow breaking of the coal. This may be due to too large a proportion of packs, to too many timbers, or to too narrow a space between the face of the coal and the packs. The remedy is to decrease the proportion of packs or the amount of timber, or to increase the open width at the face.

It is frequently difficult to determine the true source of trouble in long-wall work, and such conditions often require special treatment to overcome the difficulty and make it possible to mine the seam by the long-wall method. For example, if a hard rock and one that will not bend, but which breaks off sharp, overlies the roof strata not far above the coal, the weight on the coal face may be irregular at times, while again it may be impossible to control it at all. Although these and other conditions frequently do not permit of ideal long-wall working, a system of long wall may often be adapted to suit conditions as found.

8. **Uniform Line of Face.**—In order that a uniform weight may be maintained on the surface of the coal, the face should be advanced as uniformly and as regularly as possible, so that the roof pressure may act as nearly uniformly as possible on the entire length of the coal face. When some portions of the face advance faster than others, the uniform settlement of the roof is prevented, and those portions of the face that are behind are more heavily weighted than those in advance; consequently the coal at the points that are behind is crushed and the undercutting rendered more difficult, while at the advanced portions of the face the roof pressure is insufficient and the coal breaks slowly, and may have to be blasted or wedged down.

The regular advance of the face produces a regular and unceasing movement in the overburden, or cover, of the seam; but if the advance of the face is checked by a prolonged

season of idleness, the roof settles firmly and comes to rest, and the movement of the overburden ceases. A long-wall face that has been idle for a considerable length of time is always difficult to start again, and, for a time, the results are not as good as when the operations are uninterrupted. If the circumference of the working face becomes too extensive, it is divided into smaller arcs or sections and these are worked more or less independently of each other.

9. **Stepped Face.**—A weak top has a tendency to break just above the coal face along the line formed by the working face; if the line of face is long, this tendency to break in the roof becomes dangerous. To obviate this, the face line is broken into steps and each working place, or room, is kept in advance of the succeeding one. While this form lessens the danger from falls of roof, it also interferes with the roof pressure on the coal and breaks up the regular application of this weight to the face and in this way increases the amount of fine coal made.

10. **Crush or Creep.**—When the roof pressure, or **traveling weight,** as it is often called, advances unexpectedly in the wrong direction, portions of the face of the coal may be unduly weighted and crushed and the road packs partially or wholly destroyed. This destructive effect of the traveling weight is known as **crush** or **creep.**

SYSTEMS OF LONG WALL

11. There are two general systems of long wall—*long wall advancing* and *long wall retreating*.

In **long wall advancing,** the face is started from the bottom of the shaft or other mine opening, or at the outside of the pillar left to support the shaft or slope bottom, and advances toward the boundary of the coal area. As the roads in this system are maintained by pack walls, it is sometimes called the **gob-road system.** Long wall advancing is the system commonly used in America, and by means of it the mine is opened up rapidly and consequently early returns

are secured from the capital invested. By this method, there is no expense for narrow work, and a minimum amount of timbering of the roads is required.

In **long wall retreating,** narrow entries are driven through the coal to the boundary of the property and the

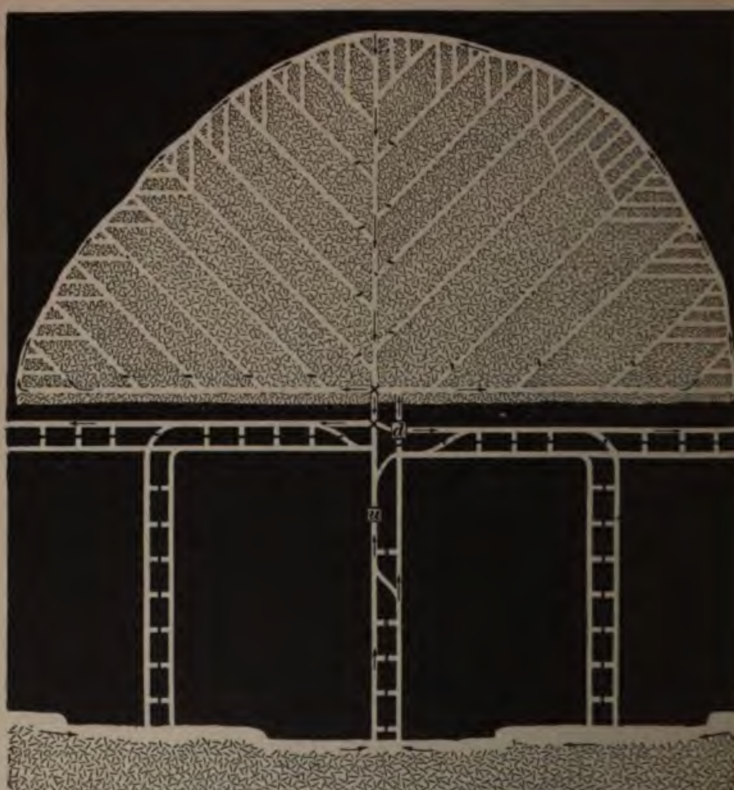


FIG. 4

long-wall face is started at that point, the coal being taken out completely as the face is brought toward the shaft. If these entries are driven entirely in the coal, there is little expense for the maintenance of the haulage roads and there is little danger of roads closing due to creep or squeeze.

The entire coal field is also prospected by means of the entries being driven to the boundary. It is probably the better system of the two, provided that the demand for coal will permit of time being taken to drive the entries. For fragile roof and soft coal, or a soft bottom, the method has many advantages, particularly for working seams lying at a great depth, as there is practically no expense for the maintenance of the haulage roads and the mined-out area is abandoned as soon as the coal is taken out. The ventilation of the face is also more efficient and less expensive.

Fig. 4 illustrates the two methods of long-wall work: The upper half shows long wall advancing by the method known as *Scotch long wall*, in which the face is semicircular and the roads are turned off each other at angles of 45°. The lower portion shows long wall retreating, in which pairs of entries are driven from 200 to 300 feet apart, depending on the nature of the coal, top, and bottom. Long wall advancing and long wall retreating are sometimes combined in the same mine, since by the long wall advancing method, an immediate output of coal is secured to compensate for the longer time required in opening up the long wall retreating.

DETAILS OF LONG-WALL WORK

12. In describing the long-wall method of mining coal, the more simple conditions relating to flat seams will be considered first, and then the various forms of long wall adapted to inclined seams as well as special forms in so far as they differ from the simple methods. The long-wall face may be started at the shaft bottom or at the boundary of the pillar left to protect the shaft and the buildings on the surface about the shaft.

OPENING OUT LONG WALL

13. Starting a Long-Wall Face at the Shaft Bottom. The long-wall face is sometimes started immediately at the foot of the shaft, or slope, without leaving a pillar about the foot of the shaft or slope. This method of opening out, if

successful, has the advantage of doing away largely with danger of a future squeeze or creep destroying the alinement of the shaft, but it is adapted only to a thin seam at a moderate depth below the surface, and the shaft must be very solidly and securely timbered. At the bottom of the shaft lining, and just below the roof of the coal, a substantial timber frame is supported on heavy posts set at each corner of the shaft and midway of each face. The coal is then taken out on each end and side of the shaft for a short distance from the shaft, and this space is filled in with well-built pack walls, made solid by ramming fine material between the stones so as to make any settlement of the shaft timber that may occur as gradual as possible. The coal may be first taken out at each side of the shaft and then at the ends; or one side and one end may be first opened out. A narrow space is left between the face of the coal and the packs. Pack walls and solid timber frames are built to form the sides of the main haulage roads about the bottom of the shaft. There is thus formed around the shaft a continuous line of face of an elliptic shape. The work is now carried forwards by taking out the coal uniformly all around the shaft, keeping the main roads well supported, and extending the pack walls as rapidly as the excavation will allow. Particular attention should be given to the building of these first packs surrounding the shaft.

14. Starting a Long-Wall Face From a Shaft Pillar. The shaft is ordinarily protected by a pillar of solid coal about the foot, the only openings in the pillar being the road necessary to bring the coal to the shaft. The size of this shaft pillar is determined in the same way as the size of the shaft pillar in room-and-pillar work and depends largely on the judgment and experience of the person opening out the mine.

When the long-wall face is to be started at the boundary of the shaft pillar left for the protection of the shaft, main entries are driven, in opposite directions from the foot of the shaft, a distance equal to half the desired diameter of the

shaft pillar. These entries *a*, Fig. 5, form the main haulage roads to the shaft bottom and from them a narrow entry, or pair of entries, encircling the shaft pillar from which the long-wall face is started. The starting of the long-wall face is one of the most important features in long-wall work, for if not properly done the work following will not be successful, or the mine may even be entirely ruined, and rendered unfit for this method of working. When opening out the long-wall face, the roof often has a tendency to break off close to the rib of the shaft pillar. If this occurs, as it has in many instances, the long-wall face is practically ruined. In order to avoid this danger, the shaft pillar is first surrounded by small pillars, which yield more readily as the weight comes on them and thus reduces to a minimum the risk of breaking the roof at this point.

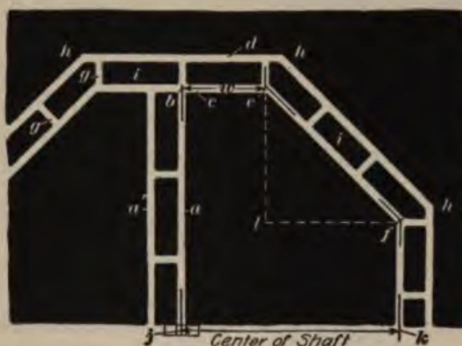


FIG. 5

15. Shape and Size of Shaft Pillar.—The long-wall face is usually circular or elliptic in outline; but on account of the difficulty of driving curved openings the entries outlining the shaft pillar are usually the sides of a hexagon, octagon, or other geometrical figure approximating the circular outline. The pillar shown in Fig. 5 is octagonal. Other considerations often require a greater width or length of shaft pillar than that required merely for the protection of the shaft. The length of double track required for shaft bottom on each side of the shaft often determines the length of the pillar in the direction of the main haulage roads, since it is desirable that this double track be protected by solid coal. In some cases it is preferred to locate the second opening or air-shaft in the main shaft pillar, and this may

increase the size of the pillar required. In any case, the lengths of the main entries and the diagonal sides of the shaft pillar should be so arranged with respect to each other as to afford the proper disposition of the main roads, so as to secure the most direct haulage from all points of the working face to the shaft.

16. Starting the Face From the Pillar.—When the main haulage road *a* and air-course *a'*, Fig. 5, have been driven a distance equal to half the desired length of the shaft pillar each side of the shaft, that is, to a point *b*, the main road *a* is extended a sufficient distance to allow the proper width of pillar between the entries *c* and *d*. The width of the pillar between *c* and *d* varies with the depth of cover, width of opening, thickness of seam, and the nature of the top and bottom rock. The entries *c* and *d* are next turned in each direction from and at right angles with the main entry *a* and driven a distance $b\,e = w$, which depends on the size of shaft pillar and the outline desired, and equals one-half the length of the side forming the end of the shaft pillar.

The distance between any two opposite sides of the shaft pillar should not be less than the calculated diameter of pillar required for the protection of the shaft. Calling this diameter D, the length of each side of a regular octagon is $.414\,D$.

At the point *e*, if the octagonal shape is used and the angles of the octagon are equal, the direction of the entries is turned 45° in a direction to encircle the shaft. The length of the diagonal side *e f* of the shaft pillar is found by subtracting w from the distance $j\,k$, which is one-half the desired width of the shaft pillar, and dividing the remainder by .707; thus, $\frac{j\,k - w}{.707} = e\,f$. The length of the two sides of the octagon parallel to the main haulage road is given by the expression $2\,j\,b - 2\,e\,f \cos f\,e\,l$. The arrangement of the entries and of the shaft pillar here given is only one of many arrangements to be found.

In order that the working face may be uniformly advanced at all points, and the roads started in the right places and

given a right direction, the work should be conducted according to a carefully drawn plan or map. In driving the entries to form the small pillars around the shaft pillar, the cross-cuts should be arranged with respect to the rooms or roads that are to be opened later. Instead of driving both entries at the same time, as just described, the entry *c* may be first driven and then the cross-cuts *g*. The ends of the cross-cuts are then joined by the narrow passage *d* about 6 feet wide. Several *skips*, or slices, are first taken off the coal face to start the work, or the entire coal face *h h h* is undermined; when this is completed, the first break of the roof takes place,

FIG. 6

brought about either by the weight of the roof, by shearing and wedging, or, if necessary, by very light shots. This is a critical time in a long-wall mine, as much depends on the success or failure of this work, and the mine manager is never at rest in opening up a new mine by this plan until the first break has resulted successfully. After the coal brought down by this break is loaded out, the miner brushes the roof of slate or shale to give him sufficient height for a car and then begins work for a second break by taking a narrow skip, or slice, off the coal entirely across the face before he begins to undermine. An undercut is then put in and a second break brought about, the miner protecting himself meanwhile by setting sprags, chocks, or props, as shown in

Fig. 6, which shows the general plan of the work after the long-wall face has been opened out as just described, one side only of the shaft being shown, as the remaining portion is identical with it. Great care is required in setting the timber and in executing all the work until the face is well started and until the roof pressure is properly brought on the coal face. The work will advance slowly at first, and the coal may have to be sheared in places as well as undercut. As soon as possible, the building of pack walls *m* along the roads should be started close up against the rib of the pillars *i*, Figs. 5 and 6. Pack walls are also sometimes built between the cross-cuts and against the pillars, in order to reenforce these pillars and to avoid, if possible, the breaking of the roof at the rib. Cogs *n* are placed at the corner of the pillar. Two or three rows of timber are maintained parallel to the face and between the packs and the working face. As the face is advanced, the row of timbers next to the packs is taken out and placed near the face.

The width of the space between the gob and coal face depends on the nature of the top. In thin seams, where the top is soft and brittle, it may not be more than 3 feet, while in a seam 10 feet thick, and having a good top it may be 8 or 10 feet wide, or more.

ROADWAYS

17. Starting the Roads.—After the breaks have been started in the roof and the long-wall face has got away from the pillar so that the working conditions at the face and in connection with the roof pressure have become settled, the cross-cuts and cut-offs for the main diagonals and the main cross-roads may be made, but this should not be done too early for fear of disturbing the roof pressure and setting up a movement that might cause a crush or a squeeze. The road packs built on the main roads are more substantial and solid than those built to protect the cross-roads, and the cross-road packs are more substantial than the packs built on the temporary roads, for the cross-roads cut off and close the temporary roads, and if a cross-road

shows signs of closing, it is always possible to reach the same coal face by a short stub road across the face of the rooms, by which the coal may be taken out on the next cross-road inby.

18. The **building of the road packs** is an important feature of long-wall work, for unless carefully built not only are they so crushed when the weight comes on them as to be of little value for supporting the roof and keeping the roadways open, but they do not form an air-tight stopping that will confine and direct the ventilating air-current. These packs are sometimes called *shanties*, for the reason that when properly built they consist of a mass of irregular-shaped stones and slate embedded in the finer waste material, such as the mining dirt, coal slack, and the dirt cleaned from the roadways; and are enclosed by substantial walls of stone. All the large stones used in building the pack should be well bedded in the fine material.

FIG. 7

The stones forming the outer walls of the pack, or shanty, should be well bonded, a number of them extending back into the center of the pack in such manner as to bind the face walls and prevent their bulging outwards when the weight comes on them. Fig. 7 represents a plan of a well-bedded road pack, with a crib supporting one end.

19. As soon as the coal is removed, the packs must be carried forwards as near to the face as they can be built without obstructing the ventilation and the work at the face. They should be kept in a continuous line through the work, and where it is necessary to start new packs in the gob during the progress of the work, it is advisable to build solid chocks as a support to the first few yards of the pack.

Packs must be carefully built of the strongest available material, and each section of the packing should be carried square and solid up to the roof and securely wedged. The size of the packs and gobs is regulated by the nature of the roof, care being taken that they are sufficiently wide to allow the roof to break down easily.

20. Cribs.—A **crib, chock,** or **nog,** Fig. 8, consists of a square building formed of logs of round timber built in log-cabin style, and either notched into each other near their ends, or laid loosely one on top of the other, but with the sides flattened to prevent their slipping. The interior is closely packed with loose slate, rock, and fine dirt, and when well built a crib offers a substantial support to the roof. Substantial cribs should be built at all road corners where there is liability of the packs or the coal being crushed. They are also built extensively throughout the gob packs, particularly where there is not sufficient waste material of which to build the necessary packs. When chocks are used instead of props, they are moved forwards in the same way as the props. Such chocks have one log laid so that it can be easily removed, so as to facilitate the taking down of the chock. If these chocks were left in, they would throw the weight of the strata above on the coal face, crushing the coal, and also on the pack walls, to their injury.

FIG. 8

21. Brushing.—When the weight comes on the road packs, they are compressed from one-quarter to one-half of their original height; and if properly built and sufficient in number the support of the roof by the compressed packs is equal to that of the coal removed. Where the floor is soft, and especially when the roof is hard, the packs may be pressed into the soft material of the floor, which creeps, heaves, or rises into the roadways and into the spaces intervening between the packs. In many cases, this heaving of the floor continues without cessation until the entire roadway is filled with the material pressed up from the bottom. In order to keep the roadways open and to maintain the headroom required for the passage of the cars and mules, it is necessary to *rip the roof*, or remove a certain portion of the roof strata over the roadway; this is called **brushing.** The removing of the soft material as it is pressed up by the weight that settles on the packs is called *lifting the bottom.* As a general rule, it is better to rip the roof than to attempt to lift a soft bottom, as in the majority of cases the more the bottom is disturbed the more it will heave, and the work must be done over and over again in order to keep the roads in a passable condition.

22. Direction of Roadways.—The general plan of long-wall work shown in Fig. 1, represents the roads throughout the mine as being turned at a uniform angle of 45°; this is often called the **45° long-wall system.** When two roads are turned off the same entry at about the same point, one of them should be turned slightly inside of the other to provide a convenient distance for laying the switches at the mouths of the roads, so that they will not interfere with each other. This is shown in Fig. 1, in the case of the cross-entries *b*, *c* turned off the main entry *a*.

In what is known as the **rectangular long-wall system,** the cross-roads are driven at right angles to the main roads. The rectangular system has the disadvantage of square corners, and a greater length of haul necessary to reach the shaft from the face. The diagonal, or 45°, system provides

easy turns at the switch points, and the shortest possible haul from all points of the face to the shaft, and hence this system is better adapted to the working of flat seams, while the rectangular system may be necessary in inclined seams.

23. Length of Temporary Roads.—The temporary roads connect the working places, or rooms, with the cross-roads, but as they are cut off from time to time by other cross-roads they are not protected by as substantial pack walls as the other roads. The length of the temporary roads

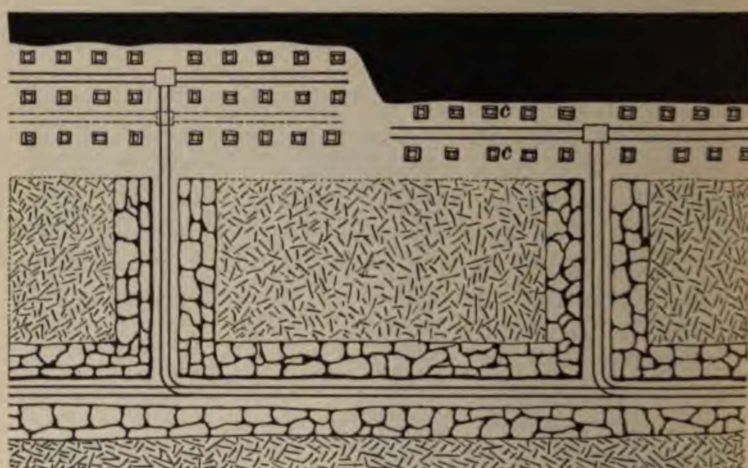


Fig. 9

may be different for each section of the mine, and must be determined in each case as the work progresses. A cross-road is started off the main road whenever the temporary road gives signs of closing. It will thus be seen that the distance between cross-roads, measured on the main entries, may not be a uniform distance for the different sections of the mine, and may even vary in the same section. Again, owing to a creep or crush closing some rooms, it may be necessary to turn a short stub road directly across the heads of such rooms or working places, the old roads in this case being gobbed tightly to counteract the effect of the squeeze.

24. Distance Apart of Roads.—The distance between the temporary roads is decided mainly by the possibility of taking the cars along the face, which, in turn, depends on the clear width it is possible to keep open between the face of the coal and packs. When it can be done, roadways are laid along the face and protected by timbers, as shown in Figs. 2 and 9. At the junction of the track along the face with the track running into the room, a turntable consisting of an iron plate allows the car to be turned. This track may be made of oak mine rails spiked to cross-ties, or of light iron rails, held together by spreaders of $\frac{1}{2}'' \times 1\frac{1}{2}''$ strap iron.

25. If the mine car cannot be taken along the face and there is a hard, smooth bottom, the coal is often loaded on a **sled,** or **buggy,** which is dragged along the face to the head of the temporary road, where it is loaded into a car. The distance between the temporary roads will then depend on the distance to which the coal can be thus conveniently carried, but is usually from 40 to 60 yards, though it has reached 100 yards in exceptional cases.

When it is necessary to shovel the coal to the road head where it is loaded, or to wheel it in barrows along the face, the roads are made from 15 to 20 yards apart, center to center.

26. Distribution of Miners at the Face.—The **web of coal** is the coal that separates and falls as the result of one undercut along the whole long-wall face or a certain section of the face. In the performance of the work, the web of coal that breaks and falls during the night is broken up and loaded out the first thing in the morning; then, when the face has been cleaned up, the miner starts undercutting a new web of coal, setting a sprag or short timber at the opening of the undercut as the work progresses.

As many miners are usually distributed on a long-wall face as are required to undercut, break up, and load out a web of coal during a shift. Under ordinarily favorable conditions, two miners can mine and handle the coal in from 12 to 15 yards of face in a day, in a seam 3 or 4 feet in thickness.

To obtain the best results, it is important to place the best long-wall miners and those who can be relied on to be at their places each day, along the faces at the heads of the main and cross-roads, as at *a*, *b*, *c*, and *e*, Fig. 10. The less-experienced men should be distributed between these points. With the face laid out in small arcs, as shown in Fig. 10, the main-road men stationed at *a* thus carry a full face all the time, the dots indicating the ends of the faces. This is the case also with the men stationed at the temporary-road heads, except as they approach a cross-road and are cut off, when they work half face a portion of the time, as shown at the face of room 2; the cross-road men at *c* alternately work full and half face. These men carry a full face just before starting a new temporary-road, as shown at *e*. As soon as a new road is started, the cross-road man divides his face with the man working the temporary road face, each being then on half face, which rapidly expands to full face as the work progresses. The temporary-road man at the end of road 2 has lost half of his face, which has been cut off by the approach of *b*; he has, however, one loose end, which is toward the cross-road, and this enables him to cut out a larger amount of coal than he otherwise could. At *c* the cross-entry is shown as having cut off the road 4, and the man has started on the face at the end of *c*. The cross-entry man at the end of *c*, is now left with a half face, but a loose end at his right enables him to advance more rapidly than he otherwise could. The face is shown in Fig. 10 as advanced in short sections, each cross-road determining a new section, and each section being advanced as a separate arc of a circle. In the figure, these sections are not as expanded, or do not cover as many working

FIG. 10

places, as they would if the cross-roads were shown their proper distance apart relative to the distance between the rooms. This gives a sharper corner of projecting coal at the face where two arcs or sections meet, but it illustrates more clearly the working of the system. It is of the utmost importance that the cross-road man should always cut in ahead of the road man, in order to maintain a symmetrical line of face.

27. Undercutting the Coal.—The work of undercutting has been described in relation to room-and-pillar work. In long-wall mining, this operation does not differ materially except in the precaution necessary to be taken to avoid danger from the fall of the coal, which is greater in long-wall than in room-and-pillar work, owing to the roof pressure thrown on the face of the coal. The undercut is made in a soft under clay, or the lower stratum of the coal if the bottom is hard. As in room-and-pillar work, however, it may be made in any suitable stratum of the seam, or in a clay parting separating two benches of the seam. The miner takes advantage of the assistance afforded by the roof pressure, by making, in succession, shallow cuts 6 or 8 inches deep across the entire face of the coal, thereby giving the roof pressure time to act on the face of the cut, the coal at the back of the cut being thus crushed and rendered more brittle and easy to mine. If, however, the roof pressure is excessive or is allowed to act on the face for too long a time, the crushed mining dirt is compacted and the mining made more difficult. The coal is undercut either by hand or by machine.

When undercutting machines are used, the coal is undercut to the entire depth in one cut, the sprags being set immediately behind the machine as the latter advances along the face. Where *cockermegs*, or *cockers* (that is, timbers used to hold up the face of the coal while it is being undercut) are used in machine work, they are put in position before undercutting is started, the cockers being removed and reset in turn, as required by the advance of the machine.

This is, of course, a disadvantage. Machines were not introduced into long-wall work as rapidly as they were for room-and-pillar work as there was not sufficient room between the face and gob in which to operate the earlier machines, and also because machine work was thought to be profitable only in thick seams, while most long-wall work was in comparatively thin coal. The long-wall mining machines now used can pass between the coal face and gob in a space that is often less than 5 feet. They are also self-propelling and as they can mine from one end of a long-wall face to the other at one run, they can be used more economically even than in room-and-pillar work, where it is necessary to move so often to new places.

Machine mining gives a more uniform advance of face than hand mining and more lump coal is produced; but the timber must be removed ahead of the machine and reset after it has passed. The labor of removing and resetting the props, moving the mining dirt back from the face, building pack walls and moving machines from one end of the working face to the other is performed by company men. Although the roof pressure, or weight, is depended on, mainly, to break down the coal it is necessary occasionally to use wedges, or even light shots.

28. Loading Out the Coal.—Long-wall work produces more large coal than any other system of mining, the web frequently falling in lengths of 8 or 10 feet, and even greater in certain long-grained coals. Considerable work is required on the part of the miner to break up this coal before loading it. This is done by means of wedges and a heavy sledge. In a thick seam, the driver often takes the car from the road head, and the miner has nothing to do but to load the car; but in a thin seam where the mule cannot enter the temporary roads, the miner generally pushes the car to the cross-entry.

TIMBERING A LONG-WALL FACE

29. Timbers are set at the long-wall face to support the web of coal while it is being undermined, to support the roof between the face and the packs, and to control the roof pressure.

30. The web of coal is supported by *sprags* and *cockermegs.* A **sprag** *a*, Fig. 11, is a short post from 1 to 2 feet long with square ends. It is set under the coal at the front of the undercut and must be well set so as not to slip out when the weight comes on it. **Cockermegs,** or **cockers,** are used to support the face of the coal in a moderately thick seam, or where the

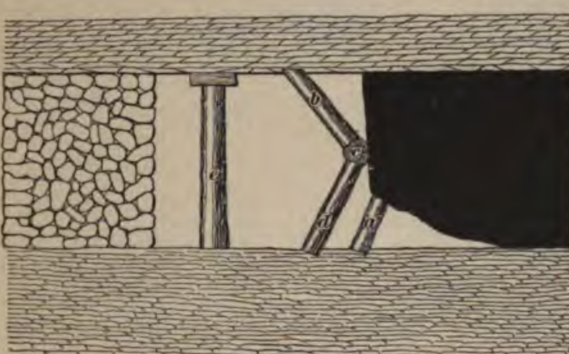


FIG. 11

roof pressure is great or the coal frail. A cockermeg consists of a longitudinal pole *c*, Fig. 11, supported against the coal face, by the cockers, or short struts, *d* and *b* set firmly in holes cut in the floor and roof of the seam. These cockers should be of such length as to be tight and firm when driven to place; they should be set before the holing is commenced.

31. Props.—To support the roof along the face, **props** set with caps as shown at *e*, Fig. 11, are used. If the roof is very tender and shelly, collars are placed above props, as shown in Fig. 12, or sometimes a hitch is cut in the coal for one end of the collar, while the other end rests on a prop placed near the pack.

At the working faces, the props should be carefully set in two or three rows parallel to the face, so as to assist in breaking the roof parallel to the general face line. The best results are obtained by also setting the props in the parallel rows in lines at right angles to the face. The breadth of roof supported by props varies from 3 to 8 or 10 feet, and the timber is only left in the 8- or 10-foot breadth for a very short time after the coal is broken down. When the coal is removed, the row of props nearest the packs should be drawn and set along the face. If an attempt is made to support too great an area of roof, the timbers will be broken and the prime object of the timbering frustrated. Therefore, timbering should be kept within the smallest possible limit, so that, without using an excessive quantity of timber, the roof under which the miner works is kept well supported, and the roof a short distance back is allowed to fall, thus relieving the timbers from excessive pressure.

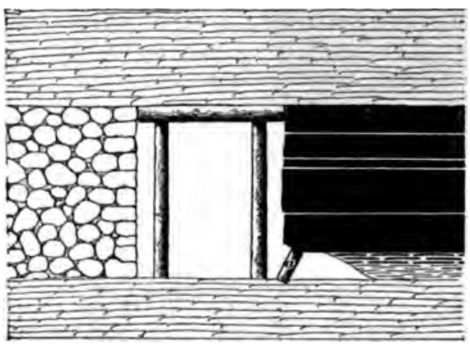


FIG. 12

32. Props are set **staggered,** as shown in Fig. 13, in many long-wall mines, but the value of this arrangement is doubtful. In Fig. 13, *i* is the track running from the face to the entry parallel to the face; *q* are the road packs, *p* are the gob packs, and *s* are brattices to direct the air-current along the face of the gob.

The weight of the roof under a cover of 200 to 300 feet will break all posts allowed to stand for any length of time. In long-wall mines in which the pressure is well regulated, and ventilation is good, timber is not needed on roadways, except where there are wide faults or *horsebacks* in the roof.

33. The element of time has an important bearing on the successful working of the long-wall method, for the reason that the faster the face can be advanced, the less time will the weight have to act on it and the roof to settle on the timber. This means that for a given amount of safety, the faster the face can be cut, loaded out, and advanced, a

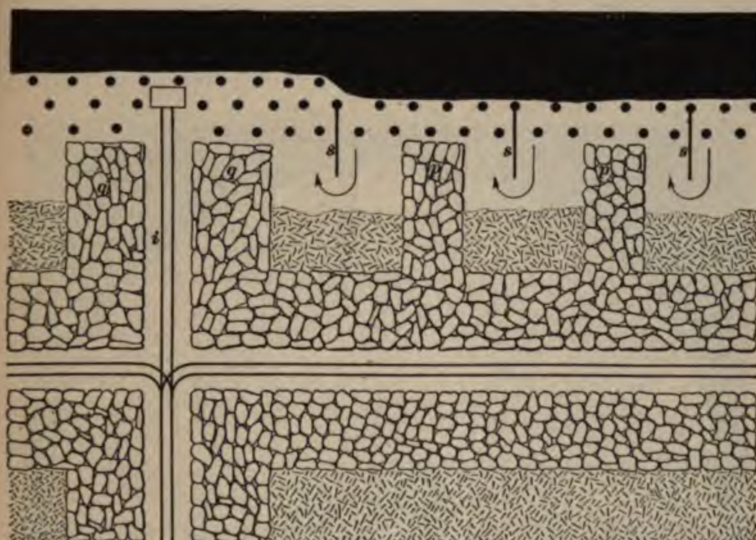


FIG. 13

correspondingly less amount of timber will be necessary and the timber will be easier to draw.

The greater the amount of ledge overhanging the solid-coal face the greater will be the weight on the timber and the greater the amount of timber required. It is therefore necessary to restrict, as much as possible, the width of both mine cars and roadways, since it is desirable to bring the timber as close as possible to the faces.

EXAMPLES OF LONG-WALL WORKING

LONG-WALL WORKING ON FLAT SEAMS

34. Scotch Plan.—The long-wall method has been used to some extent in the Interior coal basin of the United States. The Scotch system shown in Fig. 14 is the plan originally, and still largely, used in Illinois. A main entry *a* for single

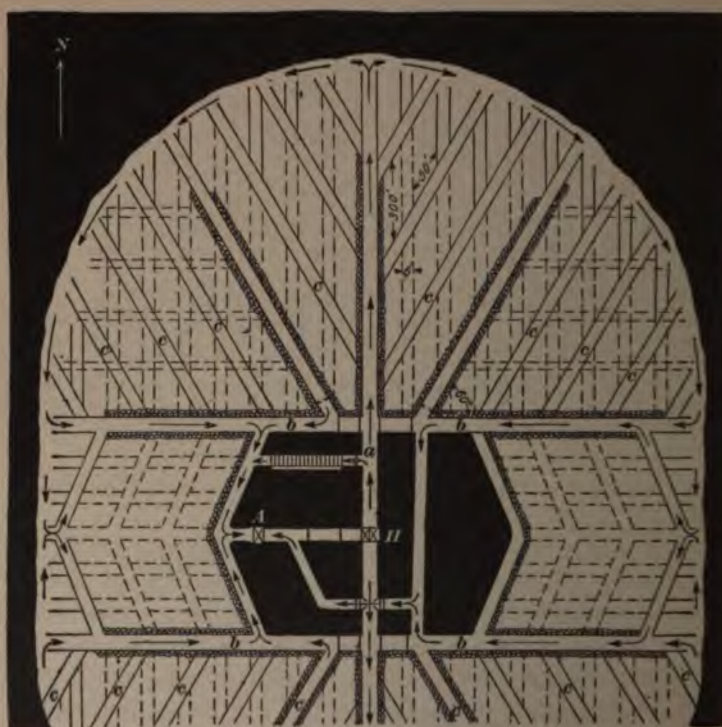


FIG. 14

track is driven from the hoisting shaft *H* through the shaft pillar, which is left large enough to protect all buildings on the surface and to contain the air-shaft or escapement shaft *A* and the stables, which are placed as shown. At the edge

of the shaft pillar, entries *b* are driven at right angles to the main entries. Diagonal roads *c* are then driven at an angle of 60° with the main road *b* and 300 feet apart. After the work has progressed a certain distance, every other cross-road is discontinued and coal is hauled out through the remaining roads; after the work has progressed still farther, the center cross-road only is used for hauling the coal out of each quarter of the mine, the coal being taken to this road through the rooms or along the face. The permanent haulage roads are shown in the plan with packs.

The main haulage roads are made 6 feet high above the rails and 10 feet wide; the cross-roads *c* are 8 feet wide. Pack walls not less than 4 feet thick, and well built of strong slate, are erected along all main roads. In the first brushing along the roads, the miner takes down 18 inches to 2 feet of slate for pack walls; and in the second brushing, the company men secure the roof and take down slate to make the roof 6 feet above the rail. Heavy cross-bars and legs are used to support the roof after the final brushing on the main entries. The legs are given 1 foot pitch in 6 feet. Permanent timbers or doors cannot be set until the roof has settled and no permanent timbers can be put in for a distance of 200 to 300 feet back from the face. When turning off the roads *c* from the main roads, an angle crib of some soft wood is put in so that it will give to the weight. Each room or working face is about 30 feet wide, and as the circle of the working face increases in size, the mine manager measures along the face and locates a new room, giving each two men about 30 feet of face to work in. When the mine is first opened out, if water is present, a gutter is made in the entry around the shaft pillar below the coal and covered with railroad ties.

The air is first split at the bottom of the downcast shaft *H* and again at the face of the main road *a* on each side of the mine, thus giving each quarter of the mine a fresh current of air, a canvass door being used in each cross-road *c* to direct the air along the working faces.

35. Rectangular Long Wall.—Fig. 15 shows a rectangular, or **square, long-wall method**, which, in some sections, is taking the place of the diagonal method just described. The entries and rooms are turned off at an angle of 90° instead of at 60°, as in Fig. 14. A pillar is left about the shaft and work begun in much the same way as in the Scotch plan. The room necks *a* are made 10 feet wide and are driven in from the haulageway 18 feet. The coal pillars *b*

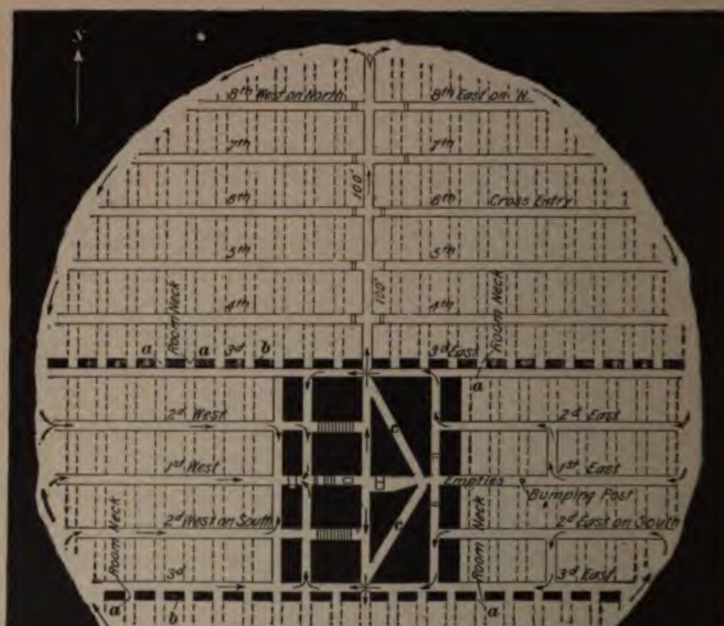


FIG. 15

are left in to protect the haulage ways at the ends of the shaft pillar.

The caging is done on one side of the shaft, empties are run to the bumping post shown and mules or motors pass through the small passages *c* called *bolt holes* to the empties. The distance between the cross-entries is 100 feet. The main entry is single-tracked, and partings, or pass-bys, are made every 1,000 feet by going into the mouth of one of the entries,

passing up the first room to the next cross-entry, and then out to the main entry again. After the work has been opened to a certain extent, each alternate cross-entry is abandoned and later more of the cross-entries are abandoned, leaving only an occasional cross-entry for haulage purposes, thus decreasing the expense for maintaining haulageways. The last room on an entry is always kept open between cross-entries as a means of bringing coal from one entry to another.

An objection to the square system is the longer haulage roads required than in the diagonal system.

LONG WALL IN INCLINED SEAMS

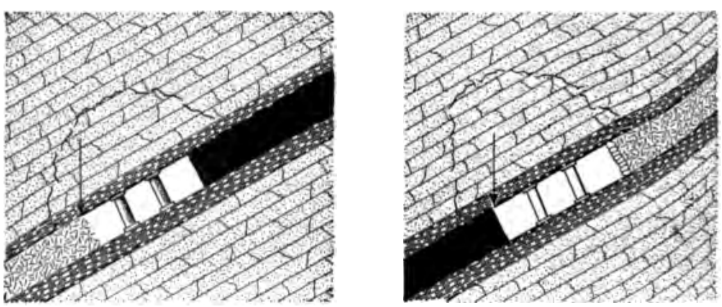
36. General Principles.—As an inclined seam cannot be advantageously worked to the dip of the lowest drainage or haulage level, the general plan of long wall, in which the face expands in concentric circles in all directions from the point of opening the seam, must be modified to adapt the system to the working of such seams, and the face is usually advanced on one side only of the lowest haulage level. The long-wall face is usually advanced along the strike in the direction of the pitch, or at some angle between the strike and the pitch of the seam dependent on the pitch of the seam and the cleat of the coal.

Again, on a steep inclination of a long-wall face, the moving of the loosened coal from the higher points along the face may injure the miners stationed at points farther down the face. To enable the miner to more readily control the movement of the loosened coal along the face, the face is often broken into steps by shearing the coal and is worked in sections. Each section of the face then has one *fast end* that must be sheared as the face advances. The crushing of the coal at the projecting corners is often unavoidable, but the inclination of the seam reduces this effect by reducing the roof pressure, which is not as great in inclined seams as in flat seams.

By arranging the face in steps, the weight of the roof is localized so that if a break occurs in one place its effects do

not extend to neighboring working places. Such step faces are generally considered a disadvantage and are not used unless it is absolutely necessary, since they increase the amount of small coal made and do not permit of systematic regulation of the weight over the entire face. It is also more difficult to insure regularity of working and of advance in adjoining places.

37. Effect of Inclination of Seam and Direction of Face on Roof Pressure.—The general effect of the inclination of the seam on the roof pressure exerted on the face of the coal is illustrated by Fig. 16, which shows at (*a*) the cross-section of a long-wall face being driven on the



(*a*) (*b*)

FIG. 16

full pitch of a seam, and at (*b*) the cross-section of a long-wall face driven on the full dip of the seam. When the face is advanced on the full pitch of the seam, a maximum roof pressure is thrown on the gob while the pressure on the coal is decreased; were the face to be advanced on the full dip of the seam a similar maximum roof pressure would be thrown on the face of the coal. Where the face is advanced in a direction parallel to the strike of the seam, or at right angles to the dip, the roof pressure is thrown equally on the gob and on the face of the coal. It is evident, then, that when advancing across the pitch at any angle between full pitch and a right angle with the full pitch the roof pressure exerted on the coal will be less than that exerted on the gob

as the angle between the line of advance and the strike of the seam is increased, as is illustrated in Fig. 17, in which the arrows perpendicular to the face of the coal represent the direction in which the face is advanced. When the face is driven up the pitch as shown in Fig. 17 (*a*), the minimum roof pressure is on the coal and the maximum pressure on the gob; in Fig. 17 (*b*), the pressure on the face of the coal is increased, while that on the gob is decreased from that in (*a*); in Fig. 17 (*c*), the roof pressure exerted on the coal is equal to that exerted on the gob.

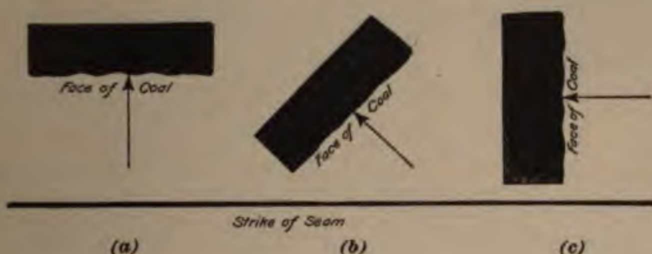


FIG. 17

38. Driving Across the Pitch.—A long-wall face is advanced across the pitch of the seam for other reasons than to regulate the roof pressure on the coal; among them are the following: The grade of the roads is decreased and the coal more rapidly handled on the jig roads or inclines down which the coal is taken from the face to the main haulage road. The inclination of the face of the coal is lessened, decreasing the danger in the work of mining, and making the coal more easily handled at the face. Breaks and slips in the roof often require that the line of face should make an angle with the strike of the seam in order to give a better support to the roof at the face. The cleavages of the coal are not always parallel to the strike of the seam, and better results may be obtained by arranging the face of the coal parallel to these lines.

39. Breaking Away of Roof.—One of the chief difficulties in working long wall in pitching seams is the tendency of the roof to slip and sink back from the face, thus taking

the pressure from the coal. For flat working it is comparatively easy to control the traveling weight on the coal; but as the inclination increases, there is considerable difficulty

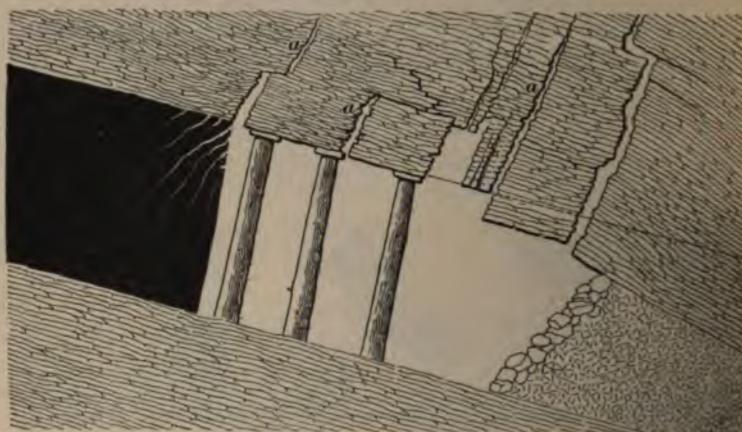


Fig. 18

in preventing the broken roof masses from falling away from the coal in the direction of the dip, and then either sinking in front of the line of face, or, if they wedge and jam too

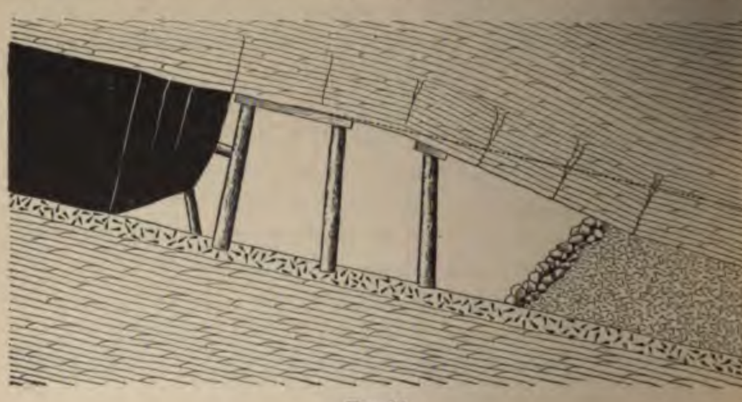


Fig. 19

tightly, they may bring an excessive pressure on the coal face and crush it, as shown in Fig. 18, which shows an actual condition existing in Staffordshire, England. Fig. 19 shows

a case where the roof has been broken properly without throwing excessive weight on the face. In this case, although the roof is broken above the face of the coal, that portion of it that is supported by the props still keeps the roof above the mining from sliding forwards and crushing the coal, as was done in the case represented in Fig. 18.

In inclined seams, it is very much more difficult to maintain the roads than in a level seam, owing to the sliding tendency of the roof.

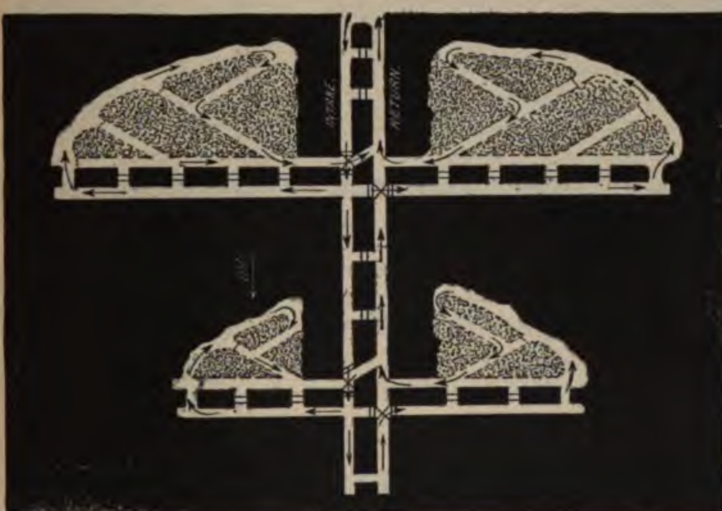


FIG. 20

40. Long Wall on Low Inclination.—In Fig. 20 is shown a long-wall face on the advancing system, in which the gob roads are built across the pitch on a suitable grade for handling the cars by mule or by hand. This method can be employed in seams having an inclination varying from 5° to 15°.

41. Fig. 21 shows a pair of levels, the upper for haulage and the lower for drainage purposes. The levels are driven on the strike of a seam, and the long-wall face is arranged at a small angle with the line of strike. The coal is lowered

from the face to the levels by the self-acting inclines i, i, which are provided with *safety holes*, or *manholes*, e, e near the face. A slant road a is driven from the haulage road to the lower, or drainage, level on such an angle that the coal may be drawn out of this level by a mule.

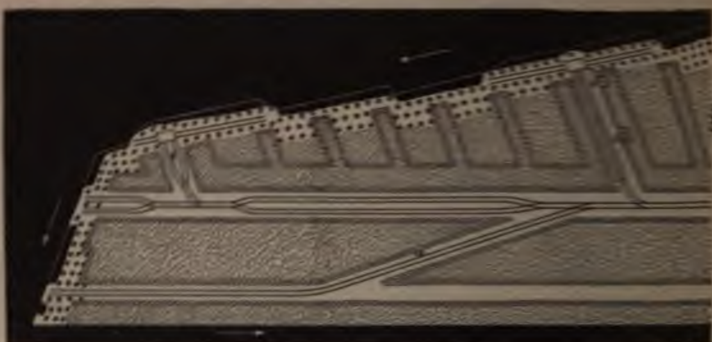


Fig. 21

42. Inclination of Seam Less Than 40°.—Thin seams of coal having an inclination of about 40°, or less, are worked in Great Britain, France, and Belgium, by driving levels or lifts on the strike of the seam in each direction to the right and left of a main slope or incline. Both the advancing and the retreating methods are used. When the retreating method is used, the levels are driven to their limit or boundary, and the long-wall face started at this point. In the advancing method, the long-wall face is started at the slope, after leaving a sufficient pillar of solid coal for its protection. In either case, the upper rib of the level is marked off in sections, the length of which depends on the conditions for getting the coal to the roads. This length varies from a few yards, 15 or 20, up to 60 or 100. Fig. 22

Fig. 22

represents the general plan where the advancing method is used.

The coal is attacked by the usual long-wall methods of undercutting and spragging the face in each section. In this system, the long-wall face advances directly up the pitch or on the face cleats of the coal. The face in each section has one fast end that must be sheared. Each section is kept from 3 to 5 yards in advance of the section next inby. The work in the first section started *a* being the most advanced, has two fast ends and is the most difficult. The waste of the seam is stowed in the space between the roads *b* maintained by solid pack walls and placed in the center of each section, so as to provide a minimum distance the coal must be handled at the face. The pack walls are started at the level by building substantial cribs that are supported against slipping by timbers set in foot-holes cut in the roof and floor. The road from the face to the level is sometimes called a *jig road*.

43. The coal is lowered from the face to the level by buggies operated by a windlass located either at the top or the bottom of the incline; when located at the bottom of the incline, the position of the windlass is permanent. The rope by which the buggy is raised and lowered passes over a block, or pulley, that is attached by a rope or chain to a timber at the head of the incline. Instead of the windlass, a form of wheel shown in Fig. 23 is often used for lowering and raising the buggy by hand. The rope is given a couple of turns around the wheel *a*, the slack end being held in one hand, while the brake band *b* is applied with the other hand by means of the lever *c* to control the

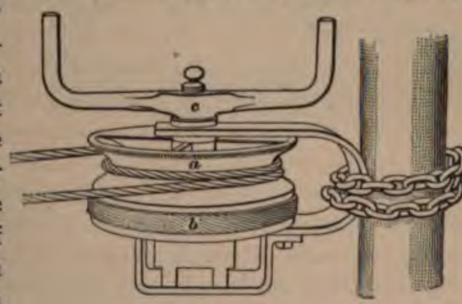


FIG. 23

movement of the buggy or car down the incline. The buggies are emptied into cars along the level and the coal carried to the slope or shaft and hoisted to the surface.

It is possible to shorten the jig roads from the face to the main haulage road from time to time, as shown in Fig. 24,

FIG. 24

by building counterlevels *a* in the waste or gob parallel to the main level *b* either connecting with one of the jig roads *c*, which is kept open and operated as a main jig, or else these counterlevels may run to a landing on the main incline or slope.

44. Inclination of Seam From 30° to 60°.—The method shown in Fig. 25 may be used for a seam pitching from 10° to 60°, but it is particularly adapted to seams pitching from 30° to 60° and where the roof and floor are good and the roof pressure is moderate. In this method, owing to the steeper inclination or to the fact that the coal works better, the working face is advanced on the ends of the coal or parallel to the strike of the seam. The working face is broken into steps, or sections, usually about 20 yards long, each section being kept from 5 to 8 yards in advance of that above it to protect the miner from the falling coal in the upper sections. In each section, there are several miners, usually three or four for a face 20 yards long, and each miner stands on a temporary platform, or on planks laid on props securely set in foot-holes cut in the roof and

floor of the seam, or else stands on a gob built up from below. The platforms also serve to protect the miners working in the lower portions of each section, from the falling coal above them. Level roads are built in the waste or gob at the foot of each section. The coal is sheared at the upper end of each section and after being undercut it falls to the road at the bottom of the section where it accumulates and is loaded in cars or buggies and transported directly to the slope or to a jig road, or main incline *a*, down which it is taken to the level *b*, and then to the slope *c*. The lowest section of long-wall face is started on the inby rib of the level *b*, the face extending a short distance below the level. A sufficient amount of coal is taken out on the lower side of the level to bring the breaks in the roof over the gob packs below the roadway. In deciding what breadth of coal should be worked on the lower side of the level, it is necessary to be guided largely by the direction of the first breaks in the roof, both on the rise side and the dip side of the opening-out places. It is generally found that the direction of these first breaks varies considerably from the direction of the main break.

FIG. 25

When the first section has advanced over 5 or 8 yards, the next section above is started, and a second level built in the gob. In this manner, the upper sections are started consecutively one after another. As the face advances, the length of the level roads increases; so to avoid the

room-and-pillar method, except that they are built in the waste instead of being driven in the coal. These chutes are kept full of coal, which is drawn as desired by opening a gate at the bottom. The miner stands on the gob, on planks,

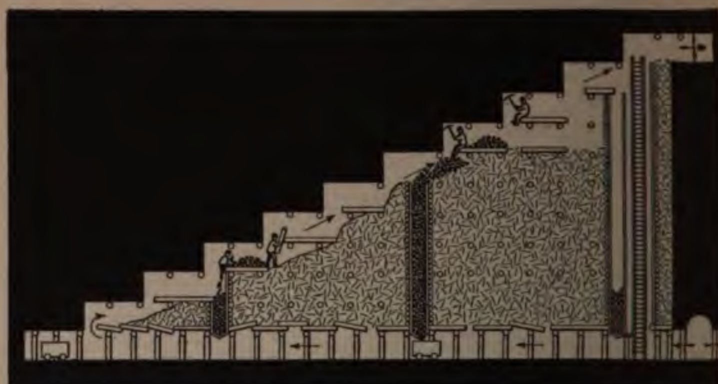


FIG. 28

or on a temporary platform reaching from the gob to the face of the coal. In the three methods illustrated in Figs. 26, 27, and 28 the risk or danger from falling coal increases with the inclination of the seam.

SPECIAL FORMS OF LONG WALL

48. Long Wall in Panels.—With the ordinary long-wall method, the mine cannot be divided easily into separate districts, as it is often desirable to do in working gaseous seams. In order to adapt long wall to the working of such seams, it is necessary to restrict the length of continuous working face by dividing the mine into panels and carrying a long-wall face in each panel, as shown in Fig. 29. Several rooms, or chambers, are turned off of a pair of entries and are connected at the inside of the entry pillar by being holed into each other. They are then driven up as a single breast by long wall advancing. The breast, however, has two fast ends, one on each side of the panel, which must be sheared as the face is advanced. Each panel has a separate

ventilating current and may be stopped off in case of a fire or a squeeze without interfering with the rest of the mine. The methods of working inclined seams as described in Arts. **40** to **47** are practically panel methods.

FIG. 29

49. The following is a description of a modified longwall system employed at Vintondale, Pennsylvania. The pitch of the seam is 8 per cent., or about 4½°, the seam is

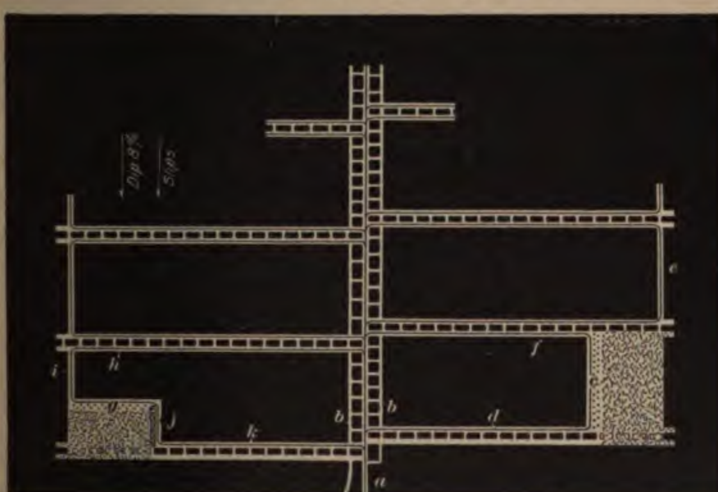


FIG. 30

about 3 feet 8 inches thick, the roof is of blue slate, and the floor of hard fireclay. The coal lies mainly under a somewhat hard sandstone cover 174 feet thick.

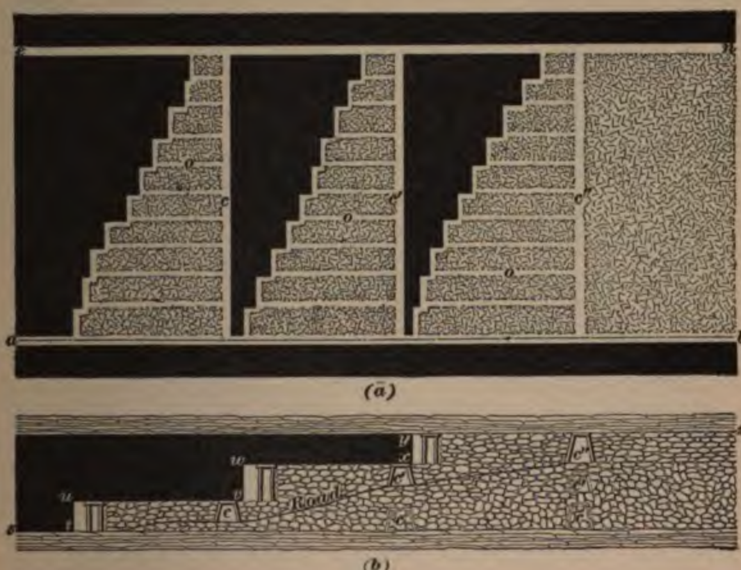
The main entry *a*, Fig. 80, is driven directly up the pitch and centrally in the coal field, bisecting it between the outcrops. This main entry is paralleled by two airways *b* as shown, one on each side for the purpose of ventilating each side independently. On the right side of the figure, at *c*, is shown one method of laying out the faces parallel to the dip. At the end of the cross-entry *d*, an ordinary room is turned up the pitch and driven practically parallel to the main heading to a connection with the next pair of cross-entries inby, as shown at *e*. The outby rib of this wide room forms the long-wall face, which is worked back toward the main entry. Empty mine cars are taken to the faces on the lower road of the inner pair of cross-headings *f* and transported along the face *c*, where they are loaded and hauled out on the upper road of the lower pair of cross-headings *d* to the main heading.

On the left of the diagram at *g*, is shown the method of laying out faces so that they are 90° with the line of pitch, so that the full influence of any roof pressure due to the pitch is exerted fully on the gob. In this case, the empty mine cars are taken into the lower road of the upper pair of cross-entries *h*, dropped through the room *i*, which connects the pair of cross-entries, then to the face *g* along which they are loaded, thence dropped through a gob roadway *j* to the upper road of the lower pair of cross-entries *k*. The gob roadway *j* has solid coal for one of its ribs, and is maintained by means of a substantial timber crib, built as the face progresses. On the left of the diagram, the faces advance directly up hill.

50. Long Wall in Thick Seams.—A thick seam of coal is usually worked in several benches of moderate thickness. The long-wall method is variously modified to suit the conditions, but the plan generally adopted, and which has given the best results in France, Bohemia, and other countries where such seams are worked, both with respect to the safety of the working and the percentage of coal obtained from the seam, is that of *close packing*, or

completely filling with waste the space from which the coal is taken. Sufficient waste is not produced, ordinarily, in the working of the seam, and waste material is brought from the surface to fill in this space.

In the working of flat seams by this method, a long-wall face is carried forwards in each bench of the coal, the face in each bench being kept from 80 to 100 yards in advance of that in the bench next above. Fig. 31 shows the general plan and cross-section of the workings at the face of a thick



(a)

(b)

FIG. 31

flat seam, the seam being divided, as shown, into three benches. The first mining is done in the lowest bench, in which the parallel main roads, *a b* and *e n*, are driven and connected by the cross-roads *c*. The roads *o* that lead to the face are protected by packs, and correspond to the temporary roads, or working places in the general long-wall method. Above the cross-roads *c* and from 80 to 100 yards back from their faces are the cross-roads *c′* in the second bench. Above the cross-roads *c′* and from 80 to 100 yards back from their

faces are the cross-roads c'' in the third bench. As the temporary roads o in the lower bench attain a length equal to the advance between the cross-roads c, they are cut off by a new cross-road in the lowest bench of the seam. At the same time, the corresponding temporary roads o in each of the benches above and which are in the same line with the roads o in the lowest bench reach their limits. The roof of the cross-road c in the lowest bench is then ripped or taken down and the road c is packed with waste on which a new

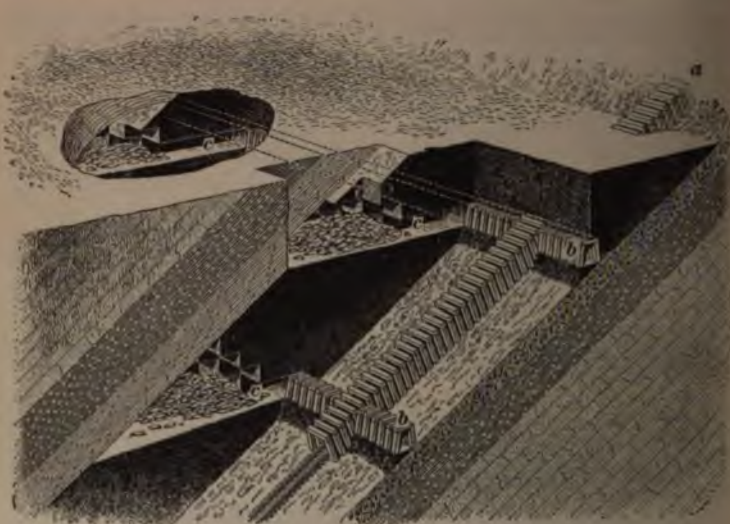


FIG. 32

cross-road c' is laid in the bench above. In like manner, the roof of each cross-road c' in the second bench is taken down, and the old road is packed with waste on which the new cross-road is laid in the bench above, as before. The main roads on each side are treated in the same manner, the road being graded from the cross-road in the lower bench to the cross-road in the upper bench, as indicated in the cross-section by the dotted line across the gob and marked *road*. This inclined road advances with the work in each bench.

Inclined Thick Seams.—In the working of inclined seams, when the inclination of the seam is moderate, ethod just described may be used for the removal of al. In steeper inclinations, a slope road is driven, as at *a*, Fig. 32, in the lower bench of the coal on the f the seam, and gangways, or levels, *b* are driven to the

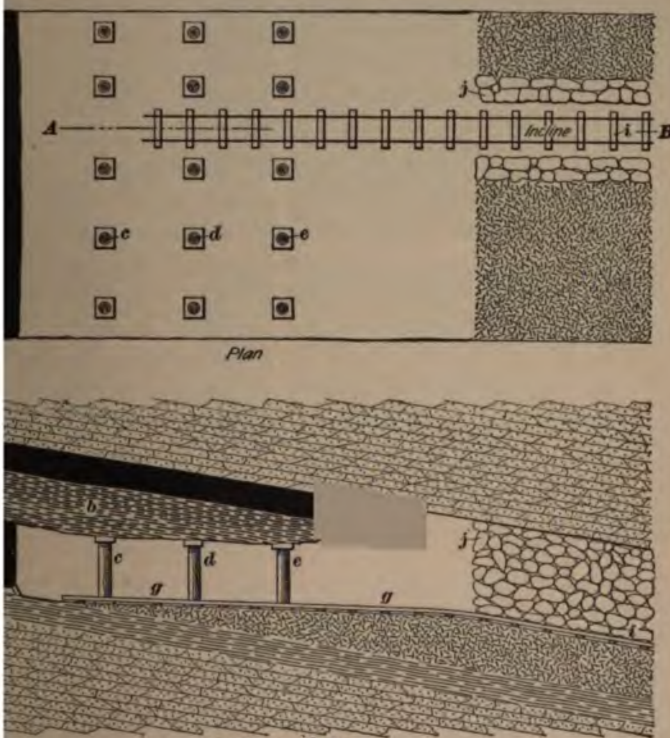


FIG. 33

and left in the seam from this slope. Cross-drifts *c* en driven from these gangways across the seam to the ock, at intervals varying from 16 to 20 yards. At of, they are holed across from one to the other, and al drawn back, on the retreating method, in horizontal from 5 to 6 feet in thickness, as indicated in the figure.

The face is also broken into steps between the cross-drifts as shown. As each slice of coal is taken out, it is often necessary to fill in the space with waste.

52. Long Wall in Contiguous Seams.—In the application of long wall to contiguous seams, the methods of work at the face do not differ from those already described. Seams have been worked in England as one seam when separated by a slate parting 7 feet in thickness. In this particular case, the lower seam was 7 feet, and the upper seam 2 feet, in thickness. A general method for working contiguous seams is shown in Fig. 33, which is a plan and cross-section of the working face. The lower seam *a* is worked first, the slate parting *b* being supported on three rows of props *c*, *d*, *e* set parallel to the face. By the withdrawal of the rear row of props *e*, the slate parting falls or is wedged down. The work of taking down the upper seam *f* then follows. The slate parting, as it falls, is broken up and leveled off, thus forming a convenient flat *g* at the top of the incline *i*. The roof above the incline is supported by pack walls *j*.

When contiguous seams are worked separately by the long-wall method, either by driving cross-tunnels between the different seams, or by separate slopes or inclines, the long-wall face in an overlying seam should generally be kept in advance of that in a lower one, as the working of an underlying seam by long wall will usually result in the crushing and crevicing of overlying seams to a certain extent.

COMBINED LONG-WALL AND OTHER METHODS

53. An advantage is often gained by combining different methods of long-wall working, and at times long-wall and room-and-pillar methods are employed in different portions of the same mine. Or the panel system is often worked long wall.

54. Combined Surface Stripping With Long Wall Retreating.—Where a portion of the coal seam lies under

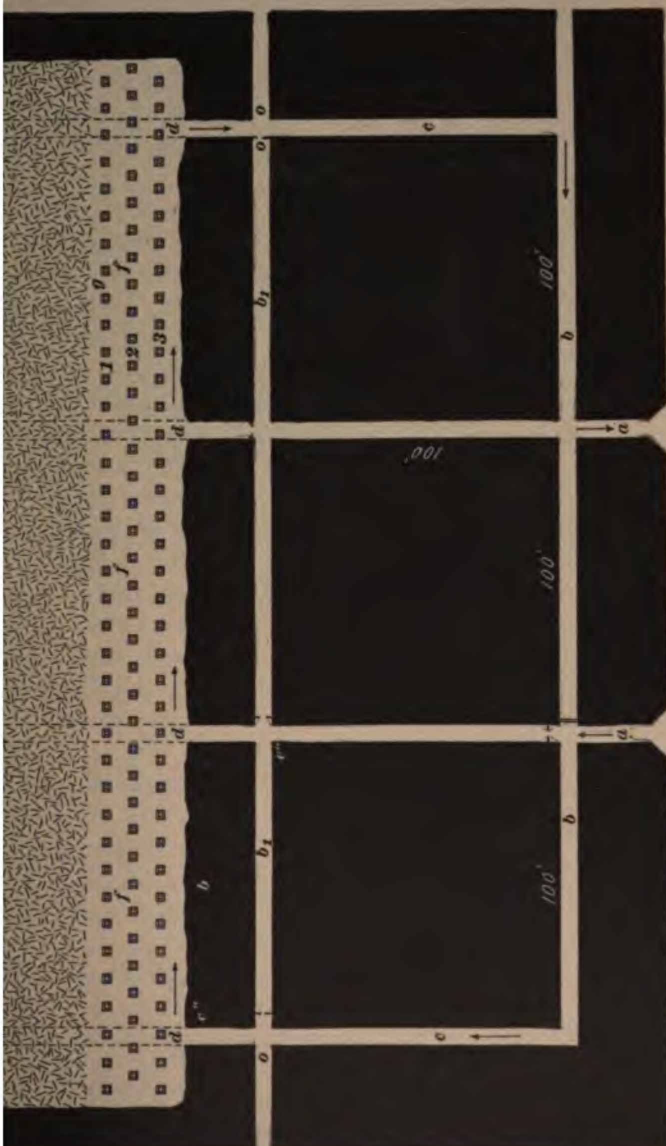


Fig. 34

such depth of cover that stripping may be done economically, a retreating system of long wall may be carried on in connection with surface stripping. By this combined system, the coal is won at a low cost, as the cheaper stripped coal balances the more expensive coal won by the retreating plan, and the stripping gives an output while the long wall is being opened out.

Fig. 34 shows an application of long wall retreating in combination with stripping. The mine in this case is opened by two drifts, or entries, *a*, which are driven in from the strippings to the boundary of the area to be worked. As soon as these entries *a* are under good cover, cross-entries *b* are driven at right angles to *a*, and from these cross-entries other entries *c* are turned parallel to *a*. Other cross-entries b_1 are driven at regular intervals. The bed of coal is thus divided into a series of square or rectangular blocks, which are generally made about 100 feet square, as 50 feet on each side of an entry is about the limit at which cars can be handled with economy, and is far enough for the miners to work from a place of safety, in the event of the top breaking over the chocks, as it sometimes does.

When the entries *a* reach the boundary, the coal face is opened out in either a circular, elliptic, or straight line by driving a cross-entry b_2, as shown in the figure, similar to long wall advancing, and as soon as the entries *c* have broken through to b_2 so as to give a current of air at the face, mining begins on the outby rib of this entry and progresses toward the stripping workings. Two miners have from 30 to 50 feet of space to mine, and the coal is mined and spragged as in long wall advancing, but the timber is differently arranged. Three rows of chocks *1*, *2*, and *3* are used at the face as shown, the row *1* farthest from the face being moved ahead to the face as fast as the coal is loaded out and there is room enough so that there are always two full rows of chocks in place, and these chocks are always kept in straight lines parallel to the coal face, so that the weight will be uniformly distributed along the working face. The rows break joints with each other, the chocks

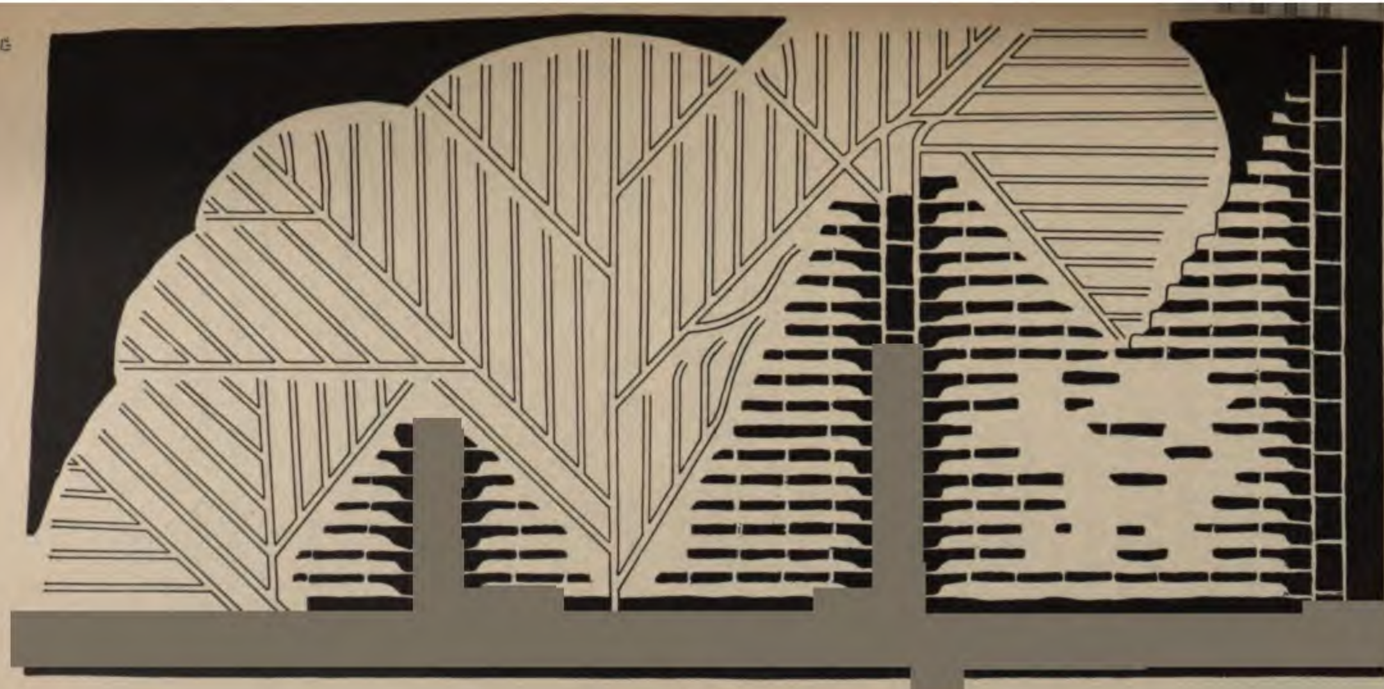


FIG. 35

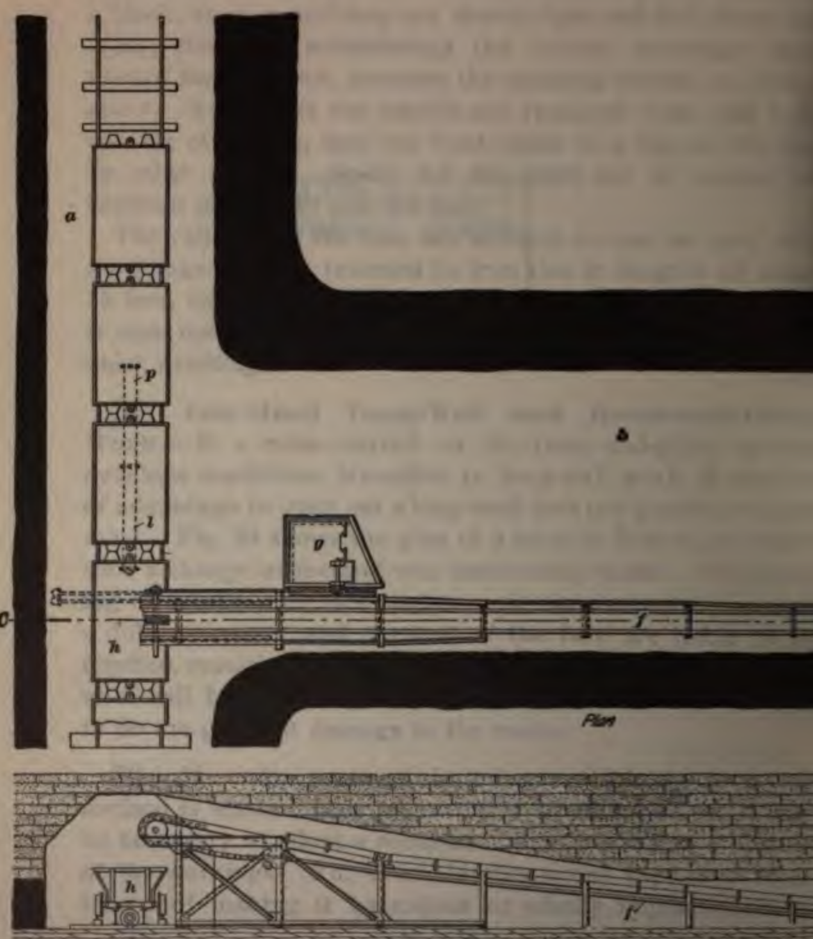
being staggered. Occasionally, it is necessary to put in props or bars to protect the miners, but these are always removed when the chocks are moved.

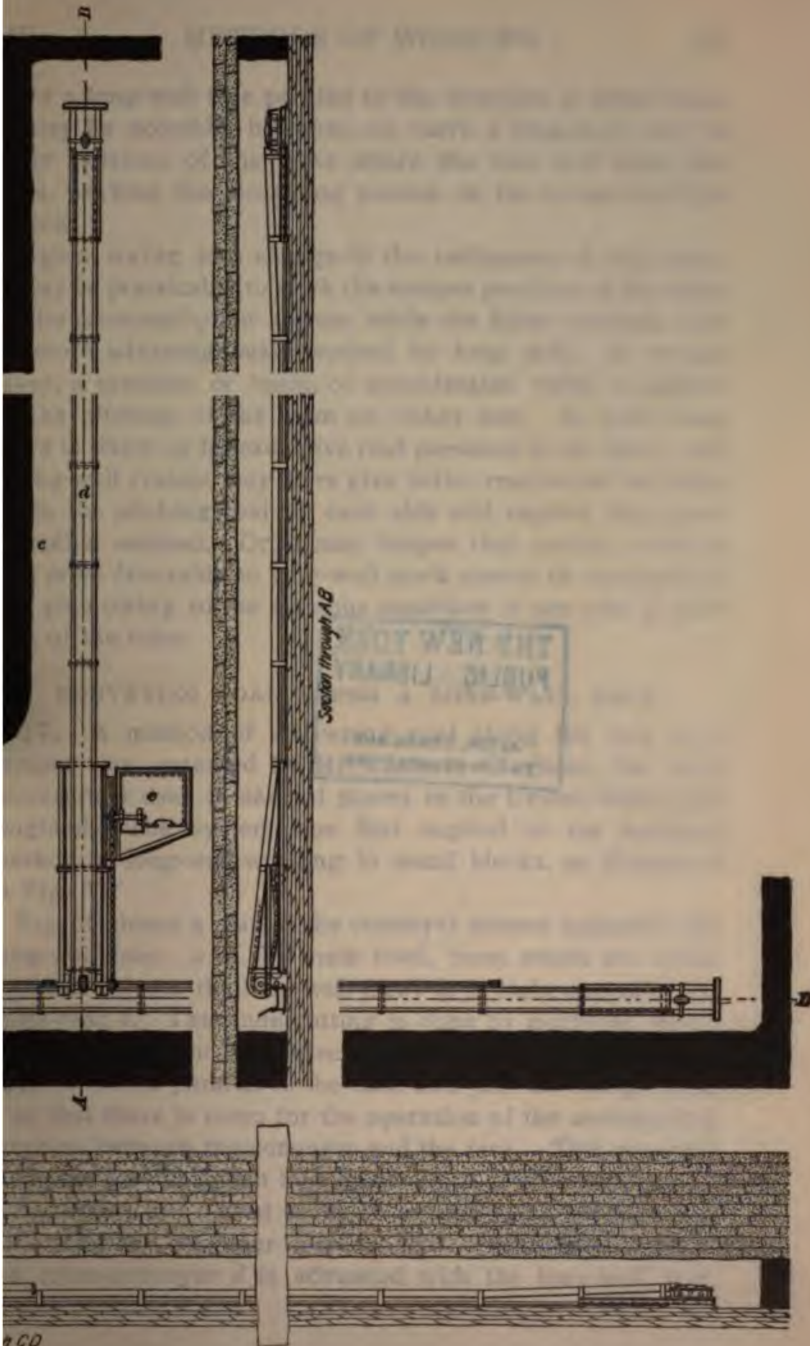
A surplus of chock timber is necessary, as much is lost in drawing, due to the premature breaks in the roof over the chocks. Sometimes props must be set near the chocks before it is safe to remove them, and chocks must be cut out, or blown out, when too firmly set for drawing. When it is desired to move line *1*, the work is begun in the center of a block, as at *g*, and they are drawn right and left from this point, the men withdrawing the chocks throwing them toward the coal face, between the standing chocks of rows *2* and *3*. As fast as the chocks are removed from line *1*, by one set of miners, they are built again in a line at the face by other miners. Space for the mine car is always left between the chocks and the face.

The rails along the face are as light as can be used with advantage and are fastened to iron ties in lengths of about 15 feet, as they must be moved often. The turntable at *i* is also made light and has a rope attached to it to admit of quick handling.

55. Combined Long-Wall and Room-and-Pillar Work.—If a mine started on the room-and-pillar system develops conditions favorable to long-wall work, it may be of advantage to open out a long-wall face in a portion of such mine. Fig. 35 shows the plan of a mine in Illinois, in which such a change of method was successfully made. The starting of a long-wall face under such circumstances is often a difficult matter, and portions of the face are liable to be crushed, resulting in a loss of some of the coal. Substantial cribs will be required at points where the crushing is liable to do the greatest damage to the roads.

56. If certain portions of a mine in which the long-wall method is worked cannot be worked by this method, it may be necessary to adopt a room-and-pillar method in a portion of the workings. For example, dangerous slips may occur in a roof making it hazardous or wholly impracticable to


a
p
l
g
C
h
f
b
Plan
h
f'



B
A
c
d
e
D
Section through AB
n CD

carry a long-wall face parallel to the direction of these slips; it may be possible, however, to carry a long-wall face in other portions of the mine where the face will cross the slips, working the remaining portion on the room-and-pillar system.

Again, owing to a change in the inclination of the seam, it may be practicable to work the steeper portions of the seam by the room-and-pillar system, while the flatter portions may be more advantageously worked by long wall. In certain cases, a syncline, or basin, of considerable width is flanked by the pitching of the seam on either side. In such case, there is likely to be excessive roof pressure in the basin, and a long-wall system may there give better results and be safer, while the pitching coal on each side will require the room-and-pillar method. Or, it may happen that certain portions of a mine favorable to long-wall work cannot be operated on this plan owing to the gaseous condition of the coal in such part of the mine.

CONVEYING COAL ALONG A LONG-WALL FACE

57. A method of conveying coal along the face by a scraper line, patented by Mr. Clarence Claghorn, has been successfully used in several places in the United States and England. The system was first applied to the modified method of long-wall working in small blocks, as illustrated in Fig. 30.

Fig. 36 shows a plan of the conveyer system applied at the long-wall face. *a* is the main road, from which the cross-road *b* is driven; the long-wall face *c* is at right angles to the cross-road *b*. The undercutting is done by machines, which can be operated in both directions along the face. The conveyer *d* is laid parallel to the face and just far enough from it so that there is room for the operation of the undercutting machine between the conveyer and the face. This conveyer along the face is driven by a motor *e* and delivers its coal into a conveyer line *f* placed in the cross-road *b* and similar, in its details, to the conveyer *d* except that it is stationary, while the cross-conveyer *d* is advanced with the long-wall face.

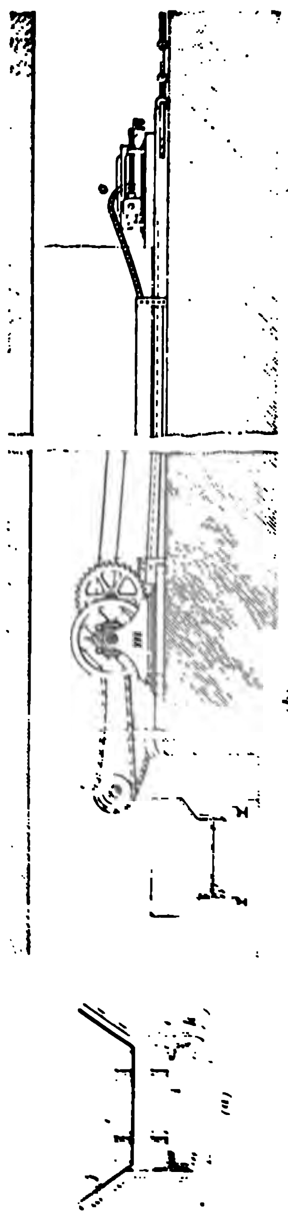


Fig. 37

Conveyer *f* is driven by the motor *g* and delivers its coal into cars *h* on the main entry *a*.

The details of this conveyer are shown in Fig. 37. (*a*) is a cross-section of the conveyer, which consists of an endless chain *i* that runs in a hopper-shaped trough *j*. The conveyer is set on skids *k* to facilitate its being moved along the bottom; or instead of the skids the side pieces *e* may be extended downwards in the form of legs. This latter arrangement is used particularly for the stationary conveyer on the side entries. The conveyer chain is driven by an electric motor *m*, Fig. 37 (*b*). The take-up device *n* and the sprocket wheel *o* at the rear end of the conveyer line are shown in Fig. 37 (*c*). The relation of the conveyer with respect to the face is shown in Fig. 38. When the undercutting of the face has been completed and the conveyer is to be moved, a row of posts is set near the face and the posts alongside of the conveyer are taken out and the conveyer line shifted by means of jacks; the timbers are then reset. The roof back of the posts and above the [illegible] is kept up by means of [illegible].

In order to move the cars a device called the [illegible]

spotter is placed beneath the track on the main road *a*, Fig. 36, and at the end of the conveyer on the cross-road. This spotter is merely a horizontal cylinder *p l*, Fig. 36, con-

FIG. 38

taining a piston operated by compressed air; on the end of the piston is a hook that grips the axle of the car. When the power is turned on back of the piston, it pushes the car forwards and places an empty car under the end of the conveyer.

COMPARISON OF LONG-WALL AND ROOM-AND-PILLAR METHODS

58. The points that must be considered before adopting the long-wall method of mining coal, in preference to the room-and-pillar method, are as follows: The roof strata overlying the seam; depth of cover; nature, thickness, and inclination of the seam; nature of the floor or underlying strata; quantity of stowage or waste in the seam or contiguous strata; surface damage and the presence of water or gas in the seam or contiguous strata; supply of timber; labor conditions; and the transportation and marketing of the product.

59. Roof Pressure.—Although it is often stated that the long-wall method can be successfully employed only when the seam lies at a considerable depth below the surface, this method has been successfully adopted under favorable roof strata where the depth of cover did not exceed 80 feet. The ideal roof in long wall is composed of tough, elastic, and pliable strata, that yield gradually by bending when the coal is removed, thereby causing a uniform settlement over the area mined and throwing a sufficient weight, or roof pressure, on the coal face to break the coal when the same has been mined or undercut.

The roof pressure depends on the depth and character of the cover or material overlying the seam. In the long-wall method of mining, the weight of the strata overlying the seam is made to settle on the waste material or the pack walls that are built as the coal is removed, hence there is practically no limit of depth beyond which it cannot be worked.

In the room-and-pillar system, there is a practical limit to the width of opening that can be safely and economically kept open, and to the width of pillar that can be left to support the increasing roof pressure without crushing. These widths of opening and pillar determine the depth of the workings that can be mined by this method. As the width of pillar increases, the expense of driving the necessary cross-cuts increases, and the percentage of coal obtained in the first working is decreased. The limiting depth is not absolute, but will vary according to conditions, and as this depth is approached, pillar mining becomes more and more difficult and expensive. On this account, the long-wall system is generally better adapted to the working of very deep seams than the room-and-pillar method.

60. Nature of Coal Seam.—Long wall is best adapted to a strong tough coal that can be undercut to a moderate depth without breaking, and to seams of uniform and moderate thickness lying flat or nearly flat. Some coal beds are not persistent, the coal at times increasing or decreasing in

thickness very suddenly and often being cut out entirely by beds of foreign material, such as rock, drift, etc. Again, large masses of iron pyrite, black bat, etc. are found in the seams. Such obstructions are unfavorable to the adoption of long wall, but with room-and-pillar they can often be avoided by leaving them in the pillars.

In steep inclinations of the seam, long wall is not as successful as in flat seams, owing to the weight being drawn from the working face.

61. Waste.—In the long-wall method, there is usually ample space for the storage underground of all waste rock, so that the expense and delay due to the haulage and hoisting of such rock is avoided. It is not always possible to avoid this expense and delay in room-and-pillar work. If there is not sufficient waste as the result of mining the coal by long wall, this method cannot be adopted to advantage unless it is practicable to bring material for the pack walls into the mine from the surface. This objection to the method is very apt to apply in the case of thick seams where a large quantity of waste or gob is required for the packs.

For the working of a thin seam, on the other hand, long-wall is particularly advantageous; for it is often absolutely essential for the successful working of a seam that all the coal be recovered, and that the expense for timber and maintenance of roadways be reduced to a minimum. This can often best be secured by the long-wall method. Where plenty of waste material is present, there is little probability of a creep or squeeze in long-wall work, except with a very soft bottom.

62. Surface Damage, Water, Gas, Etc.—In long-wall working, damage to the surface is not as liable to occur, nor is it as great, as in the room-and-pillar system of mining, the subsidence of the surface, owing to the removal of the coal, being more gradual and uniform in long wall, and seldom producing the large breaks and caving in of the surface that are so common in room-and-pillar work.

Consequently, the inflow of surface water is less in long-wall work than in the room-and-pillar system.

The presence of gas in a seam is unfavorable to long-wall work, for while the ventilation of the working face is as good, or better, in this system than in room-and-pillar work, it is less easily controlled, and a large quantity of gas liberated in one portion of the mine, is not as easily confined to that portion of the mine in extended long-wall work as in some forms of room-and-pillar work, unless some of the panel adaptations of long wall are used. In general, in long-wall work, gas issuing at one point of the face is carried along the entire working face.

63. Timber Supply.—Where timber is scarce or expensive, long wall is particularly advantageous, owing to the small amount of timber required. In long wall, much more of the timber can generally be used again and again than in room-and-pillar work, the props being drawn and set forwards as the face advances. On the other hand, in room-and-pillar work, a more abundant supply of timber is usually necessary, as the timbers cannot generally be used again.

64. Labor Conditions.—Long-wall work requires particular skill on the part of the miner, and a familiarity with the conditions affecting the success of the method. The principles involved in long-wall mining are essentially different from those affecting room-and-pillar work, and a good room-and-pillar man may not be successful in long-wall work; there is more probability of a good long-wall miner being successful in room-and-pillar work, although he is more liable to injury, as the conditions in room-and-pillar working are not as uniformly safe as those in long-wall work.

A good long-wall miner realizes more than any one else the importance of being regularly at his place every working day. A day lost causes his place to fall behind the others, which makes his work harder, and his daily output is further reduced by the amount of small coal that is liable to result from the excessive pressure where the face falls behind. The bad results are also felt by the miner working on each

side of such place, as the roof pressure is often insufficient, and the coal does not break as well as when the face is kept in a uniform line.

Long-wall work is not adapted to conditions where regularity of output is not certain, owing to the frequent occurrence of strikes, to the scarcity of labor, or where market conditions are irregular or transportation facilities uncertain and liable at any time to cause an enforced idleness of the mine. Long seasons of idleness are not favorable to long-wall work.

65. The chief **advantages** claimed for the long-wall method of mining coal are as follows: Complete removal of the coal at a minimum expense, requiring a smaller capital; an earlier development on an extended scale is afforded than by any other method of mining, bringing earlier returns on the capital invested; the output of the coal is more uniform and of a better marketable size, yielding a better price; fewer roadways are required to be maintained for the same face of coal; there is no yardage for entry driving; less timber is required on the roadways and at the face; better ventilation of the working face is secured at less expense, a minimum quantity of air being required, and fewer doors, stoppings, and overcasts are necessary; there is less liability to accident from falls of roof, and there are no pillars to be drawn; less damage results to the surface in this method; the amount of surface water in the workings is generally less.

66. The **disadvantages** of the long-wall method are as follows: To obtain the best results by this method, experienced long-wall miners are required, or those familiar with the work, and ordinary labor cannot be used to the same advantage as is often done in room-and-pillar work; where a large amount of gas is present, the ventilation of a portion of the mine cannot be controlled or the section sealed off as in room-and-pillar work, where a panel system of working is adopted; a large amount of labor must be expended in the building of pack walls; this, however, is accomplished by cheap labor; the method is not practicable where periods

of enforced idleness are liable to occur from any cause whatsoever; when the coal field is disturbed by faults, it is difficult or impossible to maintain a continuous long-wall face. When the seam is thick and the roof hard, it is difficult to obtain sufficient packing material.

METHODS OF WORKING

(PART 4)

PLAN OF THE MINE

INTRODUCTION

1. The successful and economical working of a mine depends very largely on the general plan and arrangement adopted for the underground workings. This plan includes the arrangement of the shaft bottom, the size and arrangement of all haulage, traveling, and airways, and the division of the mine into separate districts to facilitate haulage and ventilation, and finally the size and arrangement of such other openings as may be needed in connection with the operation of the mine; as, for example, underground engine rooms, stables, pump rooms, foremen's offices, etc.

In laying out a mine, the capital available usually determines very largely the nature of the underground equipment; and the plan of mine depends somewhat on mechanical equipment, as, for instance, the kind of haulage used. It is generally desired to obtain a maximum output for a minimum expenditure both for installation and maintenance; and for this reason many mine plans, particularly in small mines, are far from ideal and are not as economical and as convenient as they should be.

It is too often true that, owing to the urgent demand for coal or the haste to put the mine on a paying basis and obtain some returns on the capital invested for sinking

and equipment, the attempt is made to open rooms and mine coal before reaching such a point that the mining operations will not injure the permanency of the shaft or other openings. Such a premature development of the mine is expensive in the end, since movements may be set up in the strata surrounding the shaft and overlying the shaft bottom, pump rooms, stables, and other excavations, that may destroy the conditions of stability required for the protection of these openings. The result is that an increased expense is entailed or becomes necessary, in order to maintain the openings in their proper size and shape.

HAULAGE ROADS AND AIRWAYS

2. General Requirements.—One of the most important considerations in the general plan of a mine is the arrangement of its haulage roads with respect to the circulation of air in the mine. While this subject is treated fully in *Mine Ventilation*, it is necessary here to state briefly how the ventilation of the mine affects the disposition of the main haulage roads. In non-gaseous mines, it is advantageous to make the main hoisting shaft the upcast, so as to avoid the accumulation of ice in this shaft, which often in winter impedes and endangers the operation of hoisting. This arrangement, however, necessitates making the main haulage roads of the mine the return air-courses and when the mine is ventilated by a furnace or an exhaust fan, double doors are required on the main haulage road at the shaft bottom. Haulage can only be performed on the return current to the best advantage when a blower fan is used. It is important to avoid, as far as possible, doors on the main haulage roads of a mine.

In a gaseous mine, it is often necessary that the main haulage roads be made the intake airways so as to avoid the risk of the ignition of the gas often present in dangerous quantity in the return current. In this arrangement, the drivers on the main roads of a gaseous mine can generally work with open lights, and electric locomotives can be used for hauling. It is customary in this arrangement for

the mine to be ventilated on the exhaust system, since the use of a blower fan would usually require doors on the main haulage road and obstruct the haulage system.

NUMBER OF ENTRIES, HEADINGS, OR GANGWAYS

3. The haulage ways in a bituminous mine are known as *entries* or *headings* and in an anthracite mine as *gangways*. These are used not only as haulage roads by which the coal is taken to the mine opening and the empty cars returned, but also as traveling-ways and as airways for the ventilation of the mine. There are several methods of arranging these entries or passageways, known as *single entry*, *double entry*, *triple entry*, etc.

4. The **single-entry system** shown in Fig. 1 is one in which a single entry is driven forwards and rooms turned off from this entry at regular intervals.

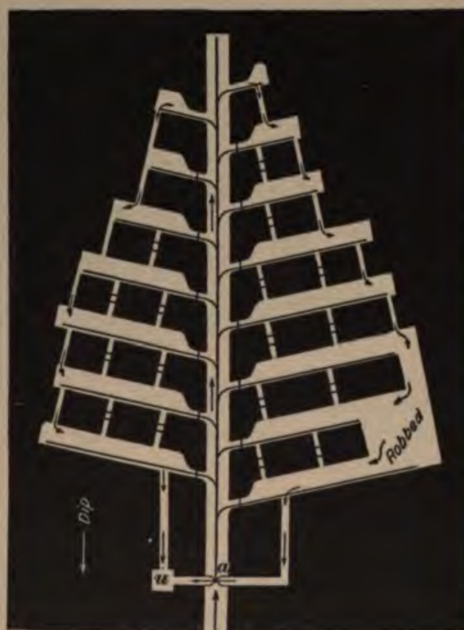


FIG. 1

The entry, which is also the main haulage road, generally serves as the intake, the air being conducted by it to the last rooms on the entry; the air enters these rooms and passes back along the working faces through the break-throughs, from room to room, and returns to the first rooms working on the entry, and thence by cross-cuts it reaches the upcast shaft *u*, shown on the left of the main road, near the entrance or mouth of the mine. The air returning through the rooms

room-turning, as far as it is desired, for the purpose of prospecting the seam or to prepare for rapid work when the demand for coal requires a large output.

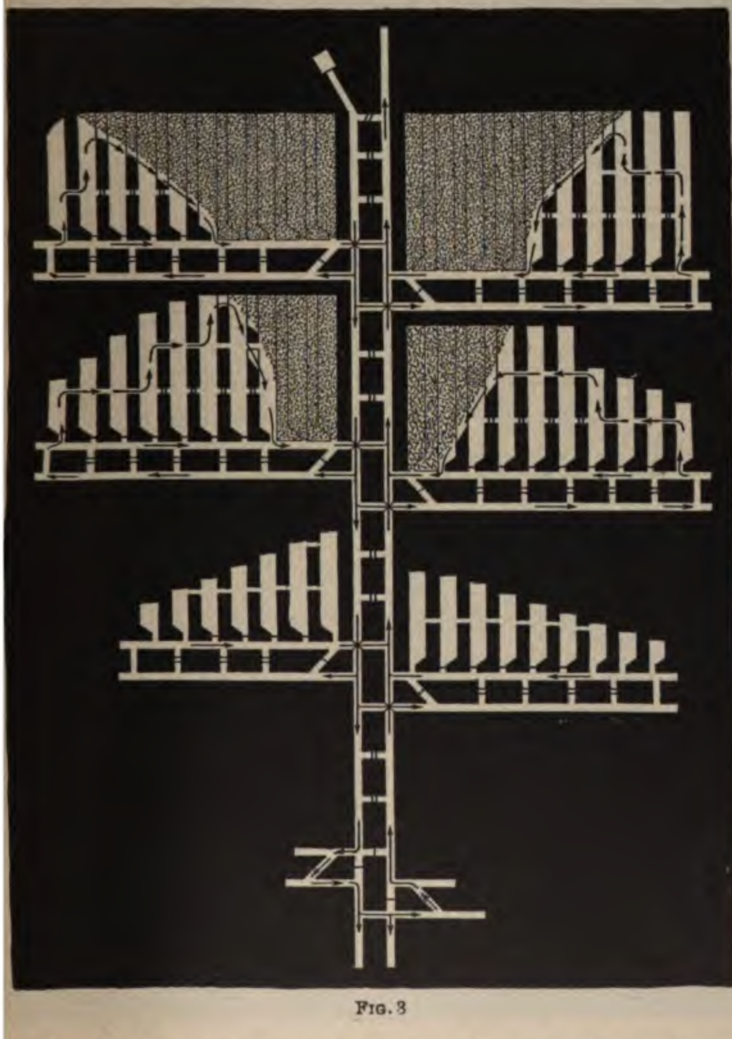
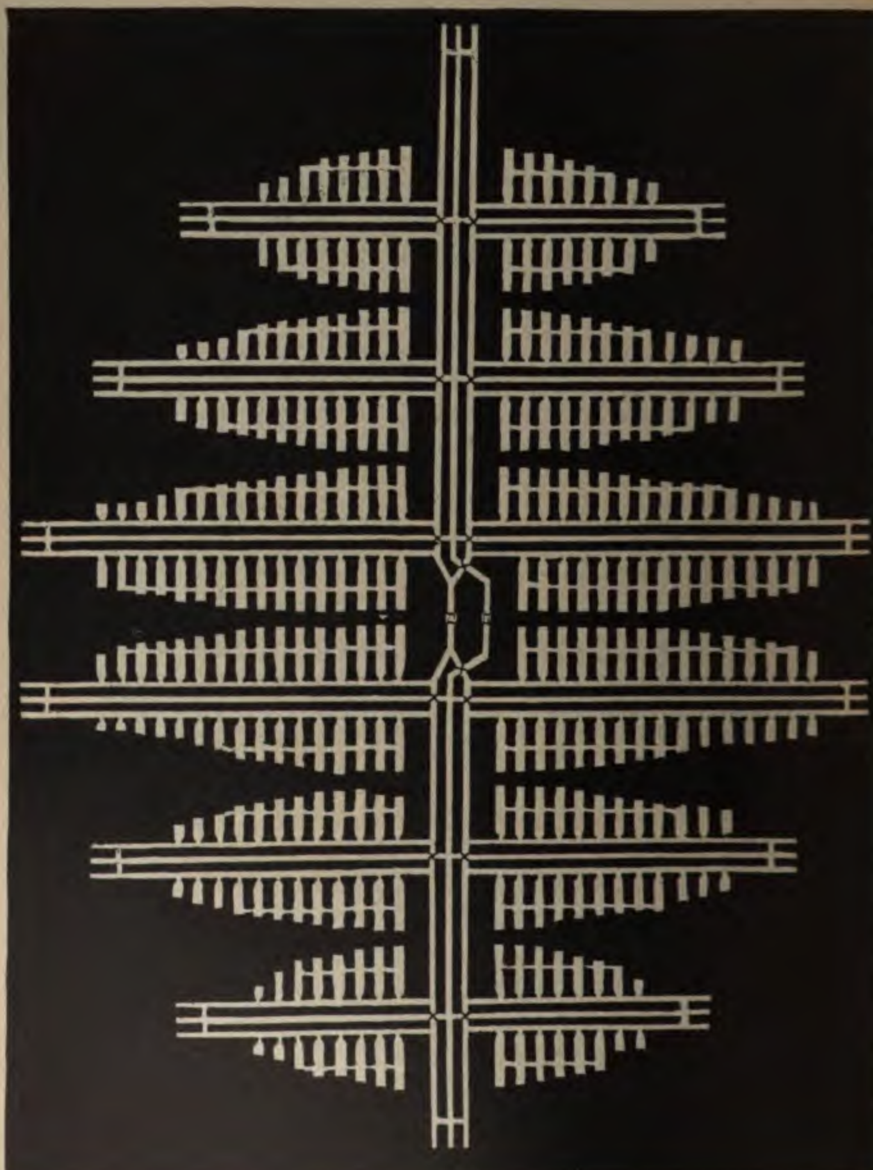


FIG. 3

6. In the **triple-entry system**, three entries are driven side by side, as shown in Fig. 4. The center entry is usually



made the intake and the main haulage road for the mine, while the two side or flank entries are made the return air-courses for their respective sides of the mine. Overcasts are usually built at the mouth of the center entry of each set of cross-entries to conduct the return current over the haulage road. By this means, doors are avoided at the entrances to cross-entries, and a separate air split is provided for that section of the mine. This system, although requiring a greater outlay, is often absolutely necessary in the working of a gaseous seam, to which it is particularly adapted. It is also used where it is not possible to drive a single entry of sufficient width for a double-track haulage road or where single or

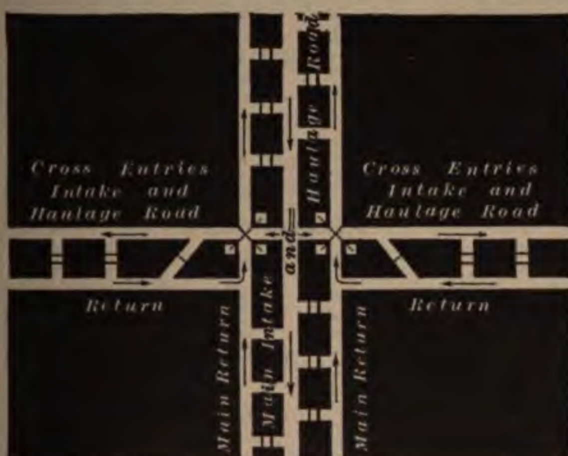
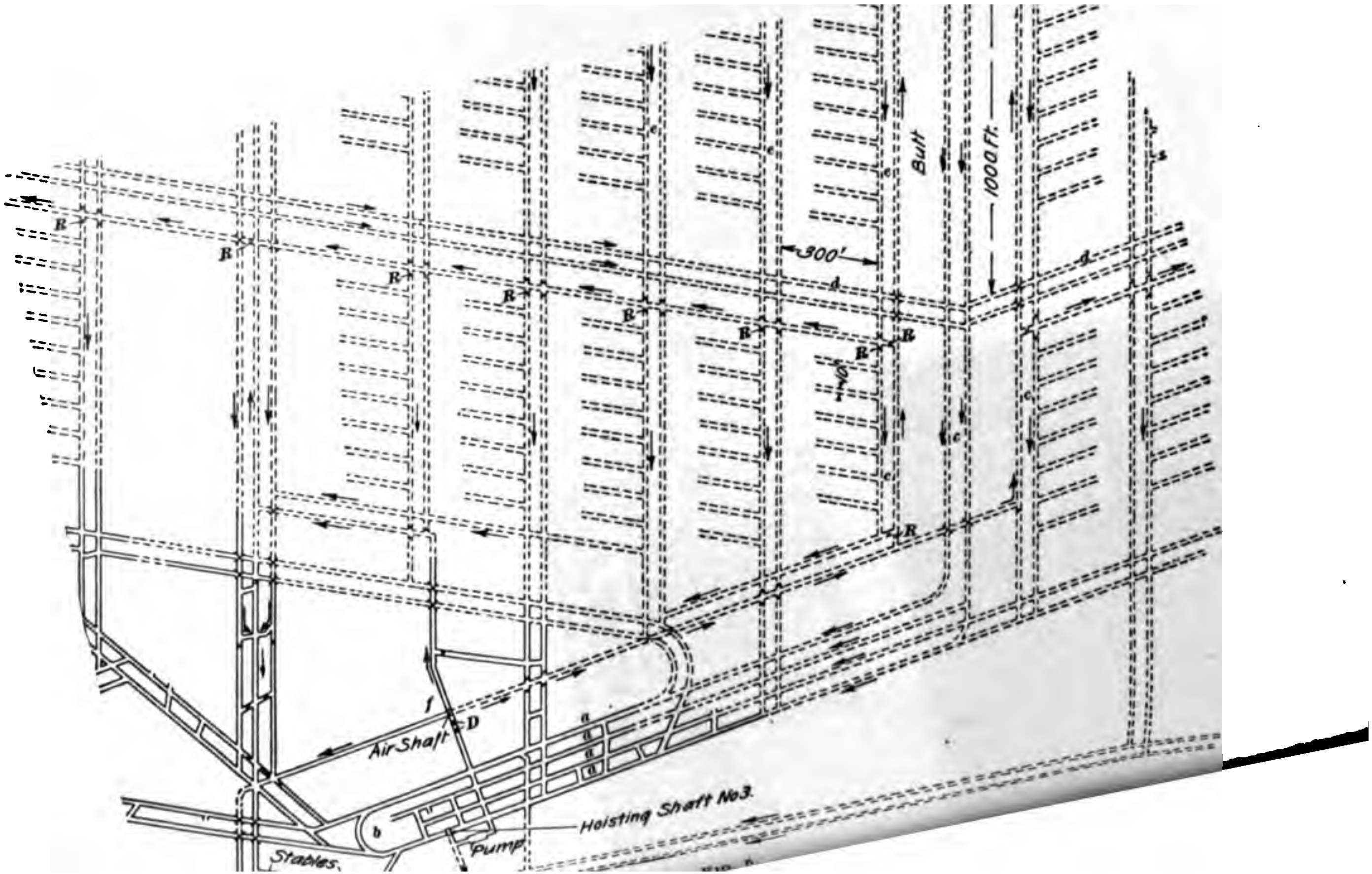


Fig. 5

double entries of sufficient cross-section to give the required quantity of air cannot be driven or economically maintained on account of the poor roof or creep. Sometimes, this system is applied to the main entries only, of a mine, the cross-entries being driven double, as shown in Fig. 5.

7. A **four-entry system,** sometimes called the **quadruple-entry system,** has been used at times in the operation of very gaseous mines having a large output of coal. This system, however, is used in comparatively few mines,



Butt
1000 Ft.
300'
Air Shaft
D
Hoisting Shaft No.3.
Pump
Stables.

owing to the great expense of entry driving it entails. In some special cases, six or more entries have been used about the shaft bottom to facilitate the handling of the coal, but it is seldom that more than three entries extend into the main workings, and by far the larger number of mines use the double-entry system.

Fig. 6 shows the four-entry system as used at the Oliver No. 3 mine, Uniontown, Pennsylvania. To reach the approximate center line of the coal field, four parallel entries *a* were driven nearly on the face of the coal for 1,600 feet from the hoisting shaft *b*. At this point, six parallel headings *c* were driven on the butt of the coal and extended until they reached a point about 500 feet from the outcrop, when the number was reduced to two. Right and left from the main butt heading *c* face headings *d* were driven in pairs 1,000 feet apart, thus dividing the main butt heading into 1,000-foot sections, while the face headings were subdivided by pairs of butt headings *e* driven parallel to the main headings at intervals of 300 feet along the cross-headings. Rooms are turned off these butt headings 10 feet wide and with 80-foot centers. No rooms are worked within a radius of 500 feet of the shaft, and all the main and butt headings are flanked by pillars 150 feet wide. The face headings *d*, right and left, are protected by 200-foot pillars to the rise and 80-foot pillars to the dip.

Ventilation is provided by four main splits from the bottom of the air-shaft *f*. These main splits are subdivided so that the air-currents are controlled by regulators and the air-currents can all be reversed by simply changing the doors in the fan house at the top of the air-shaft. The only doors used are the double doors *D* on the heading between the air-shaft and the hoisting shaft.

SIZE OF ENTRIES

8. The **size** of any mine passage depends primarily on its use and also on the nature of the roof, floor, and coal. The cost of maintaining wide roadways or passageways under a bad roof or where the floor has a tendency to heave

or where the coal is frail, often prevents their use and necessitates narrower openings. The thickness of the seam also affects the width of the roadways for a given output of coal, by reducing the height of the car in thin seams, and requiring a greater width of car and consequently greater width of roadway for the same capacity or output. The amount of the daily output of coal is also a factor determining to a large extent the size of the haulage roads required. In a coal seam 6 feet thick, with a good roof, and when the coal is clean and does not yield much gobbing material, the width of a single-track entry is generally from 8 to 10 feet. As the amount of material to be gobbed increases, the width is increased, if the roof will permit; but occasionally entries are driven only 6 feet wide owing to poor roof. The general practice is, however, to drive entries as wide as roof conditions will permit so as to avoid yardage as much as possible.

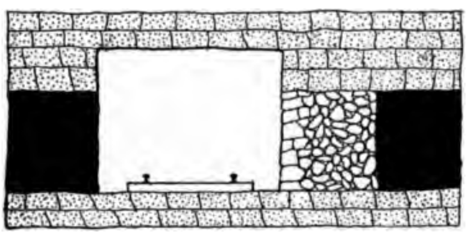


FIG. 7

In thin seams, where the roof must be taken down or the bottom lifted to provide headroom on the haulage roads, an entry is often driven 12 or 14 feet wide where the conditions with respect to the roof and coal will permit. By this means, the cost of driving is paid by the coal taken out, there is no charge for yardage, and room is provided for stowing the waste material taken down from the roof. This waste is built along the side of the road as a pack wall, or *building*, as it is called. Fig. 7 shows a cross-section of an entry where the roof has been taken down to afford headroom and the waste built up at the side of the road.

The size and shape of airways depend on the circulation required in the mine and are treated fully in *Mine Ventilation*, Part 1. The height of an entry is determined largely by the kind of haulage used; but, when possible, all main entries should be at least 6 feet above the rail.

Break-throughs between entries are usually made about the same width as the entry and at a distance apart determined by law or by the gaseous condition of the coal.

9. Sidings, Partings, Lyes.—These terms are applied to the space or track room at the inby end of a main haulage road, or to a similar space at a point of the road where cars that are collected from the working places by the drivers are made up into trips to be hauled to the mine opening either by mules or by some form of mechanical haulage. Both the loaded and empty tracks of a parting are often made level, although the loaded track is at times given a slight grade in favor of the loaded cars.

The terms *turnout* and *pass-by* are often used synonymously with siding, parting, and lye, though strictly speaking they apply more particularly to any portion of a single-track haulage road where a double track is laid for the purpose of affording passing room for the loads and empties. These turnouts are placed at more or less regular intervals along the road.

DIRECTION OF ENTRIES

10. Direction of Entries in Flat Seams.—As shown by the several mine plans already given, the haulage roads of a mine in flat seams are laid out, as a general rule, with the cross-roads at right angles to the main roads. In many cases, the cleat or other physical features of the seam determine the direction of the road; but, if physical conditions permit in working a large property, it is of advantage to have the roadways of the mine as nearly as possible parallel to or at right angles to the meridian or to the property lines, as this simplifies the matter of direction for the miner and also facilitates the laying out of a systematic plan for the workings. This is particularly true in sections of the country where the surface lines of the properties have been laid out by the United States Land Office on the rectangular system.

It often happens, however, that to facilitate the working of the coal at the face or to secure better drainage and haulage,

it is necessary to lay out the main and cross entries with reference to these points. Thus, a well-defined cleat of the coal, fault lines or slips in the roof, or a gradual but uniform dip may determine the direction of the entries and rooms.

In working small properties and especially in the working of leased properties, known in some sections as *royalties*, it is often necessary to drive certain roads so as to conform to the property lines dividing the different properties. Often a road or pair of entries is driven on such division line between two properties, so that all the coal on one side of the entry belongs to one property, and all on the other side to the other property.

If a generally flat seam has one or more **synclines** or **basins**, with the coal rising on each side by a gentle grade, it is important to lay out the haulage roads in these basins as far as practicable so that the coal from the rooms will gravitate toward the entries. The labor and cost of handling the coal from the face of the rooms to the roadway is thereby greatly reduced by avoiding the necessity of taking the mules into the rooms to pull out the loaded cars.

Faults and rolls are common in many coal fields and often these are parallel throughout a district; in the Iowa coal field, for instance, their direction is northwest and southeast. If a seam of coal occupies a long narrow basin between two such rolls or faults, it will generally prove advantageous and economical to locate the main haulage road in the center of the basin without respect to the points of the compass or the direction of the land lines.

11. Direction of Entries in Inclined Seams.—The general practice in inclined seams is to drive the main haulage road either on the full dip or rise of the seam, and turn cross-roads, also called levels or gangways, on the strike of the seam to the right and the left of the main slope, that is, at right angles to the main road. The exceptions to this general rule are very few, since the direction of the main slope should, in general, be such as to favor the haulage of coal from the levels on both sides of the main road, and any

deviation of the main slope from the full dip or rise of the seam would favor the cross-roads on one side at the expense of those on the other side, reducing the angle to be turned off in the one case, but increasing it in the other.

In inclined seams, the principle feature determining the direction of the roadways is the *inclination of the seam*, the other features so important in flat seams being of minor importance, and often wholly unconsidered. The direction of a cross-road must be such as to insure the natural drainage of the road and afford the proper grade for haulage; this grade varies usually from $\frac{1}{2}$ to 2 per cent.; and the direction of a roadway that will have any desired grade in a seam of a given inclination is found by the following rule.

Rule.—*The sine of the angle that a road in an inclined seam makes with the strike of the seam is equal to the ratio of the tangent of the slope angle of the road (percentage of grade) to the tangent of the angle of inclination of the seam.*

Expressed as a formula, this rule is,

$$\sin a = \frac{\text{tan slope angle of road}}{\text{tan inclination of seam}} = \frac{\text{percentage of grade of road}}{\text{tangent inclination of seam}}$$

in which a = angle between roadway and strike of seam.

EXAMPLE.—The main slope of a certain mine is driven on the full dip of the seam, whose inclination is 15°, the direction of the dip being N 25° 30′ E. It is desired to know the direction in which to drive cross-roads to the right and left of this slope, so as to give a 1-per-cent. grade in favor of the loaded cars in each case.

SOLUTION.—The tangent of the angle of inclination 15° is .26795, and the grade of each cross-road is .01. Then, substituting these values in the formula, the sine of the angle that each cross-road makes with the strike of the seam is $\sin a = \frac{.01}{.26795} = .0373$. From a table of sines and cosines, the angle whose sine is .0373 is found to be 2° 8′. Hence, in order that each cross-road shall have a 1-per-cent. grade in favor of the loaded cars, the road must be driven to the pitch of the seam and make an angle of 2° 8′ with the strike of the seam. The direction of the strike, being at right angles to that of the dip, is S 64° 30′ E to the right and N 64° 30′ W to the left of the main slope. The direction of the required road on the right of the main slope is, therefore (64° 30′ − 2° 8′ = 62° 22′) S 62° 22′ E; and the direction of the road on the left of the main slope is (64° 30′ + 2° 8′ = 66° 38′) N 66° 38′ W. Ans.

ALINEMENT AND GRADE OF ENTRIES

12. Alinement of Entries.—It is important that the haulage roads be as straight as practicable, so as to increase the safety and reduce the friction and wear and tear of the rolling stock, tracks, ropes, etc., in connection with haulage. Less coal is also then shaken from the cars and the roadways are kept cleaner and freer from accumulations of dust.

Where the seam is irregular, and particularly where it is also inclined, in order to maintain a level track or uniform grade on the roadways they are often made to conform to the irregularities of the seam, giving rise to a winding roadway that is poorly adapted to mechanical haulage. Where the road in such a seam is driven on a straight course, there are numerous sags and rises called swamps and hills, which are likewise disadvantageous on a haulage road and an element of danger where mule haulage is used, since a failure to properly sprag the cars may result in a fatal accident. Where mechanical haulage is to be adopted on such roads, it is generally preferable to maintain a straight course on the roadway, filling the swamps and cutting the hills and thereby establishing a uniform grade for the haulage road. The length of time the road is to be maintained as a haulage road, the expense of establishing a uniform grade by cutting the hills and filling the swamps, and the advantage to be gained by so doing, must all be carefully considered in deciding the manner of driving the levels or roads in such seams.

13. Cut-Offs.—Sharp angles are always to be avoided on haulage roads, and as far as practicable on air-courses, by substituting a curve for an angle or by means of a diagonal road. A **cut-off** is a short road connecting two haulage roads and intended to reduce the length of track or roadway to be maintained, or to replace sharp corners or turns on a haulage road by an easy curve or by a short diagonal track. Fig. 8 shows a cut-off formed by a road *a* maintained through an abandoned room, for the purpose of reducing the length

of track, which otherwise must be maintained in both pairs of entries. By the use of this cut-off, the road from *b* to the main haulage road *c* is abandoned, the coal from these entries being taken out through the cut-off. Practically all the rooms have been worked out and abandoned along this piece of

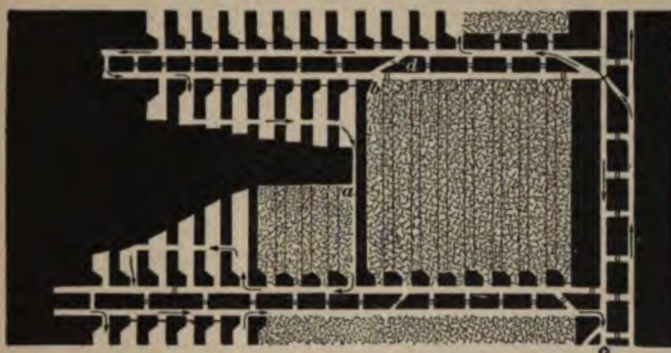


FIG. 8

track. The cars from the few rooms still working along the upper entry are *backswitched* to the cut-off through the diagonal cut-off *d*. The cutting out of long stretches of track in this manner often reduces the expense for the maintenance of the

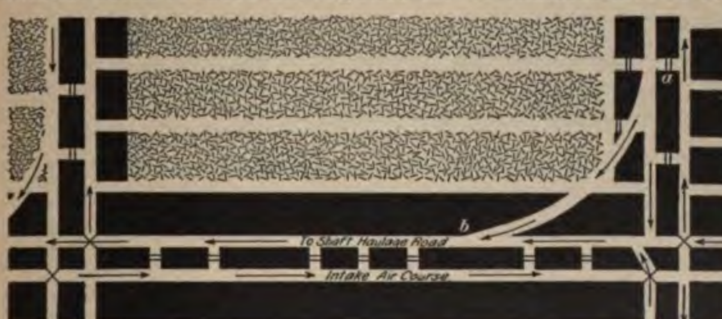


FIG. 9

mine roads. The expense of maintaining a gob road is often greater than that of an ordinary road on an entry; but, in general, it will be found advisable to use a cut-off.

Fig. 9 shows another form of cut-off often laid out at the mouth of a cross-entry, by cutting through the entry rib and

the gob in the abandoned rooms next to the main haulage road to a point on the cross-road. In laying out such a cut-off, previous to starting the work, it is necessary to determine the angle that the track on the cross-road at *a* makes with the track on the main haulage road at *b*, and the degree of curvature to be used.

14. Grade of Entries.—In flat seams, the grade depend on the slight inclination of the seam if there is such inclination. On the main haulage roads the grade is the same as the pitch of the seam; and on the cross-roads it is just sufficient for haulage and drainage purposes. Where the seam is undulatory, a roadway driven in the seam has a variable grade. When mechanical haulage is introduced on such a road, it is customary to reduce the sharpest of these grades by cutting the hills and filling the swamps along the road. This is often done to the extent of lifting 8 or 10 feet of bottom for short distances, or brushing the roof an equivalent amount. The result is that a good haulage road is made having a fairly uniform grade over considerable distances.

In an inclined seam, any desired grade can usually be obtained by altering the direction in which the roadway is driven. A road driven exactly on the strike of a seam would be level, but to facilitate natural drainage and gravity haulage the roadways are always driven at a slight angle with the strike of the seam, and toward the rise.

15. Prospect Entries.—Single entries are often driven for prospecting purposes through a fault or roll in a coal seam. Such entries are usually driven as narrow as practicable, in order to avoid the handling of any more dead material than is necessary. Air is carried to the face of the entry by means of an air brattice placed along the side of the entry a short distance from one rib. If coal is struck beyond the fault, the entry may be easily widened later, if desired.

On account of a fault, the continuation of the seam is often lost, and it must be prospected for in the strata above or below the opening. The direction of faulting may often be

discovered by a close inspection of the strata as they appear on the rib at the line of fault, as the direction of throw is often indicated by the direction of bending of the strata at the fault.

It often happens at a fault that the coal is interstratified by thin spars that indicate very clearly by their direction the position of the faulted seam. When none of these indications are present, an attempt is made to identify the strata beyond the fault with the strata overlying or underlying the seam. Another and often more definite and practical method is to drive a narrow place across the fault, and continue it a sufficient distance to permit of drilling holes upwards and downwards a sufficient distance to locate the lost seam. It is necessary to observe particular care in approaching a fault that is known to exist, or after it has been discovered and in driving across the fault into the measures on the opposite side, as the conditions with respect to gas or water may be materially changed by the fault. A non-gaseous seam may become gaseous beyond the fault or vice versa, and water may be encountered or lost in the faulting of the seam.

SHAFT OR SLOPE BOTTOMS AND LANDINGS

16. Definition.—The term *shaft bottom* relates in a general way to all that portion of a mine immediately surrounding the main hoisting shaft, and embraces all the openings in the shaft pillar, or all the openings maintained in a seam in close proximity to the shaft and used in connection with the making up of trips of cars to be hauled throughout the mines.

As all the coal from the mine during the entire period of its operation must pass over the tracks at the shaft bottom to the cage and be hoisted to the surface, it is necessary that the shaft bottom be so arranged as to afford the greatest facility for handling the coal brought to the bottom of the shaft, and caging the same, and for returning the empty cars to the face to be reloaded, as well as for the passing of men and supplies and waste or refuse in and out of the mine.

The output of a mine whether large or small depends in a great measure on the arrangements at the shaft or slope bottom and whether such arrangements are adequate for the quick handling of a sufficient number of loaded and empty cars and of supplies to insure a large daily output.

The main feature of a shaft bottom and the one on which successful and economical hoisting depends is the arrangement of the entries and tracks extending from the landing at the foot of the shaft or the slope inby a distance varying from 50 to 100 yards according to the size and capacity of the mine, and forming one terminus of the main haulage roads of the mine. Other features of the shaft or slope bottom are the *mine stables*, *pump room*, *engine room*, when a haulage engine is located below ground; the *lamp station* in a gaseous mine; *tool shanty; oil house; mine-boss shanty; hospital room* for the care of the injured; *wash room*, etc., according to the completeness of the mine equipment.

17. Shaft Landings or Stations.—Where coal is hoisted from different levels in a shaft, there are landings or stations at the junction of the levels and the shaft where cars are pulled off and pushed on to the cage. These landings are made wide if the shaft has more than one compartment, and it is generally necessary to timber them securely. Fig. 10 shows a shaft landing and the method of timbering it. For the proper support of the cage landing and the wings or keeps, on which the cage may rest, a cross-sill *a* is

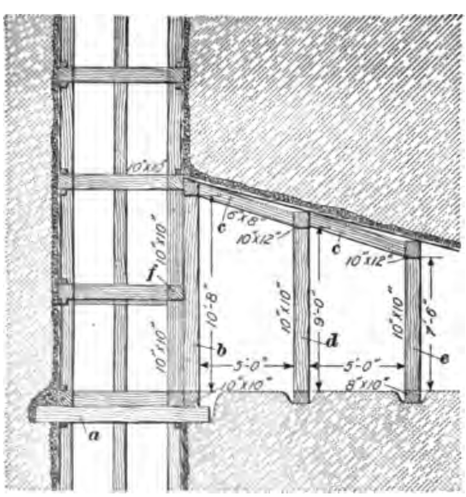


FIG. 10

placed across the shaft and on this the frame *b* is raised and bolted to the shaft frame. On the collar of frame *b* rafters *c* are placed and these extend back to the frame *d*. Similar rafters *c* rest on frame *e* to protect the landing and strengthen the roof at this point. After this timbering work has been accomplished, the wall plates of the shaft are cut out at *f* to afford passage for the cars when caging. A landing frequently extends on both sides of a shaft, so that the loaded car bumps the empty car off the cage.

In inclined seams, the term landing or station refers to the track room at the mouth of each level driven off the shaft or slope. The length of the landing is such as to afford ample room for the handling of the cars in each level or lift. Landings are usually made by widening out the gangway or level driven on the strike of the seam. A shaft or slope bottom is often called the lower landing.

The walls of a shaft bottom or landing must be substantially supported. Where timber is used for this purpose, large posts and caps are used, and they are often set skin to skin, so as to prevent falls of roof material. The practice is becoming very common, however, of using masonry arches or masonry walls for the sides and steel beams for the roof support; details of this method of construction will be given later.

ARRANGEMENT OF SHAFT BOTTOM

18. The arrangement of a shaft bottom or of a landing will depend on the conditions at the surface and in the seam, which vary widely, so that in different localities there are many different arrangements of shaft bottoms adapted to special conditions. A few of these plans will illustrate some of the methods most generally adopted for overcoming the natural difficulties, and adapting the general plan of the mine to special conditions. If the natural conditions will at all permit, the length of the shaft is perpendicular to the main haulage road.

Fig. 11 represents a common form of shaft bottom in use in flat seams. The main haulage roads *a* are laid out on

the double-entry system and are driven in each direction in line with the shorter dimension of the shaft. The cross-entries *b* are turned off at right angles from the main entries at the end of the shaft pillar.

The air-shaft is sometimes located in the shaft pillar, as shown, 50 to 100 yards from the main hoisting shaft, though if this is the only second opening it must be placed, according to the law in many states, at a certain minimum distance from the main shaft. The main and air-shafts should be

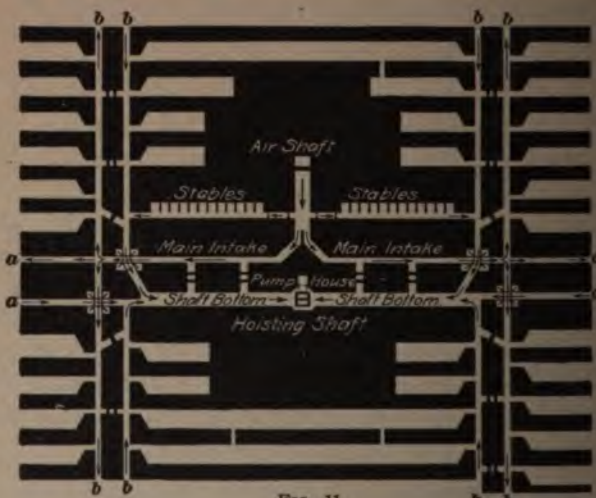


FIG. 11

connected in the seam as early as possible, so as to establish a reliable circulation in the mine passageways, and in making this connection the future development and general plan of the mine should be considered so as to furnish the most direct course for the air to the different sections of the mine. The mine stables are located between the air-shaft and the first pair of cross-entries on each side. The pump house is close to the foot of the hoisting shaft, as a compartment of this shaft is used as a pumpway. Manways are provided around the foot of the hoisting shaft, between the shaft timbers and the rib, the rib being cut out as shown. In a deeper mine, where a greater shaft pillar is required

ıan that shown in Fig. 11, the first two or three rooms ‹tending toward the shaft from the first pair of cross-ıtries would be omitted.

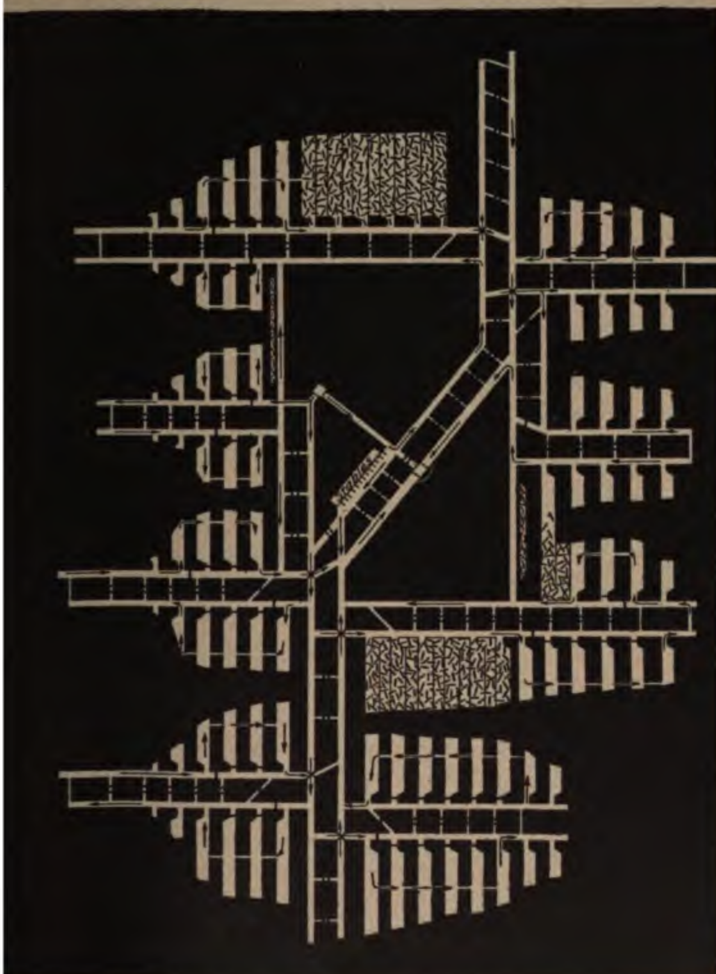
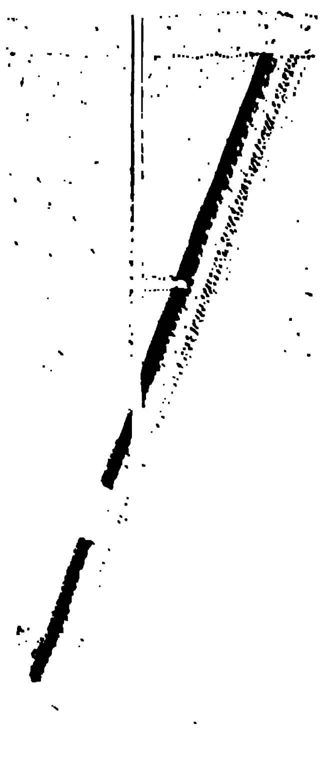


FIG. 12

19. In Fig. 12 is shown a form of diagonal shaft bottom ›mmonly used when the arrangement of tracks at the sur-ıce, and the consequent direction or position of the shaft does

not conform to the direction in which it is desired to drive the main entries. The shaft bottom is laid out square with the shaft for convenience of caging, but at each end of the shaft bottom the main haulage roads are turned in the direction in which it is desired to drive these entries. Numerous modifications of these two general forms of shaft bottom are in common use.

20. Width and Height of Shaft Bottoms.—Shaft bottoms are generally made wide enough to allow for two tracks, one for empty and one for loaded cars, and a space between the two tracks wide enough to allow men and mules to pass between the loaded cars. Occasionally under a good roof, three tracks are used, but this is an exception. The ordinary width is from 14 to 20 feet; where wooden collars are used, a wider span necessitates center props under the bars. When steel I beams are used as collars these ... necessary. [illegible]



of strength in timbering and lagging, and a less height hinders work on the bottom as well as interferes with ventilation.

21. When an inclined seam is opened by a shaft, cross-tunnels are driven from the shaft to the seam at different levels, as shown by the vertical cross-section in Fig. 13; and at the points where these tunnels reach the seam, gangways or levels are driven to the right and left in the seam. In this case, a *landing* is provided in each level. This is generally done by widening the gangway at the cross-tunnel to provide room for a double track, since it is cheaper to widen the gangway than to drive a wide cross-tunnel in the rock strata. Each level in the seam is called a *lift*, and these are generally numbered from the surface down, or the level is named by its depth from the surface; thus, the 100-foot level, the 200-foot level, etc.

22. Arrangement of Tracks at the Bottom of the Shaft.—The arrangement of the tracks at the shaft bottom

FIG. 14

must be such as to expedite the work of caging. The shaft bottom is usually double-tracked its entire length, the straight track being the loaded track, the empty track switching into this at its inby end. Fig. 14 shows the general arrangement of these tracks when coal is received on both sides of the shaft. The loaded track on each side is in line with the empty track on the opposite side of the shaft. This arrangement facilitates the removal of the empty car from the cage at the same time that the loaded car is being caged, the latter usually bumping the empty and starting it off the cage. Owing to the supply of coal not being uniform on both sides of the shaft, *cross-caging* often becomes necessary; that is to say, the tracks must be arranged so that the loads from one side of the shaft may be placed on

either cage, the empties being removed on the same side of the shaft from which the coal is loaded. For the purpose of cross-caging, the cross-over tracks *a* shown on each side of the shaft are used. Much time is lost where cross-caging is necessary, since the empty car must be pulled back out of the way before the loaded car can be run on to the cage. In Fig. 14, *b* is a foreman's office and *c* a pump room.

23. Steel plates are sometimes used on the landings where the cars are small and easily handled. These plates *a*, Fig. 15, cover the entire width of the entry, and extend from 2 to 3 yards back from the shaft. The tracks terminate

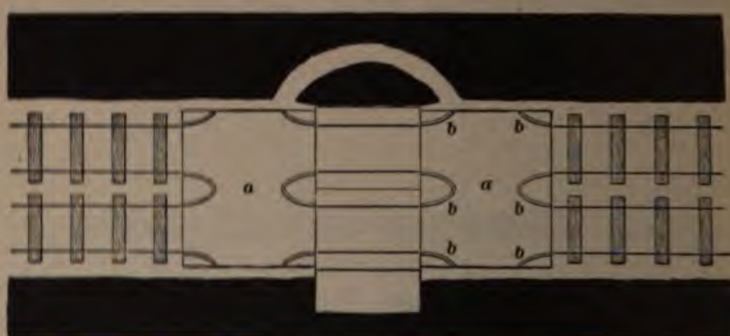


Fig. 15

abruptly at the edge of the plates. Small guide rails *b* are riveted on the upper surface of the plates, to guide the car on to the tracks and on to the cage. If the loaded cars weigh 3,000 pounds, or more, the plates last only a short time, being cut rapidly by the flanges of the wheels. The use of plates somewhat expedites the work of cross-caging where this is necessary.

24. When coal is received on one side of the shaft only, an arrangement of tracks such as shown in Fig. 16 is often adopted, by which the empty car, when bumped from the cage *s* by the loaded car, descends a short, sharp grade to *h*, and then by its own momentum ascends a short grade *r* called a kick-back and returning by gravity passes through a

spring latch at *b*, by which it is automatically switched and passes around the shaft by the track *g* that connects with the empty track, which is from 2 to 3 feet lower than the level of the loaded track. At times, the track leading around the shaft passes through a cross-over to an air-course or parallel entry occupied by the empty track, instead of returning to the main shaft bottom where the loaded track is located.

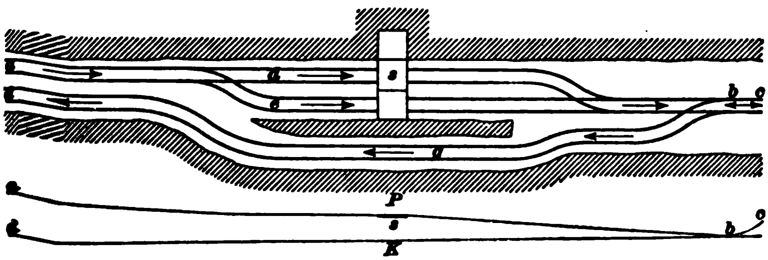


FIG. 16

Sometimes, the loaded track is in line with the center of the shaft, instead of as shown in the figure, the switch allowing the cars to pass to either cage as desired.

SLOPE BOTTOMS

25. The term **slope-bottom, landing,** or **station,** is applied to the arrangements at the foot of a slope, and has the same significance with regard to a slope that shaft bottom has with respect to a shaft. The arrangements for a slope and a shaft bottom are similar except for the differences required by the inclination of the bed. The same length of double track is required on a slope bottom as on a shaft bottom, and the loaded track is also usually the straight track. The tracks on the slope bottom are connected with the slope tracks by automatic switches that work so that the slope track is always kept straight. These switches should have a rather long lead to lessen the risk of cars being derailed.

The tracks on the slope bottom seldom cross the slope at the slope track level except where a slope carriage is used; and in that case the loaded cars sometimes bump the empties off the carriage just as at the bottom of a shaft.

26. Fig. 17 shows a plan *A* and a profile *B*, in outline, of a method of connecting the roads of a level or gangway, to the road in the slope. At a distance of 40 or 50 feet above the landing, or gangway, *g*, the slope *s* is widened out to accommodate the branch *b*. This branch descends with a gradually lessening grade, until at the level of the gangway it turns into the main loaded track *l*. A short distance above the gangway and below the switch *b* a hinged bridge *d* is placed, which, when lowered, forms a connecting platform

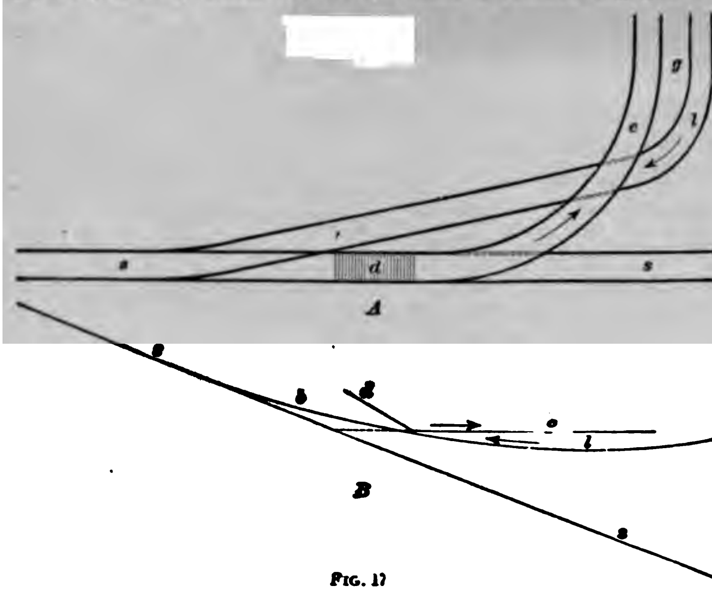


FIG. 17

or bridge by which the empty cars are taken off the slope. The empty track *e* is about 6 feet higher than the loaded track *l*, and is carried over it on a trestle.

The figure shows the plan as arranged for a single slope, or one side only of a slope taking coal from both sides. When coal is to be hoisted from this landing, the bridge is closed, the empty cars lowered in the slope run off over the bridge, the cars unhooked from the rope, and the hook and chain thrown down to the track below on which the loaded cars are standing; the loaded cars are then attached to the

rope and hauled to the main track on the slope and hoisted. This plan can only be economically employed in a seam of moderate thickness that will not require the taking down of a large amount of the top. The cars can be handled on the landing by gravity.

27. Fig. 18 shows an excellent method of laying switches in either thick or thin seams where the pitch does not exceed 20°. When there is only one track in the slope and coal is to be hoisted from both sides, the same arrangement is used on each side; but to avoid complications, such as crossings, etc., it is better to locate one of the switches on the main track farther down the slope, as indicated by the dotted lines. The empty track *e* joins the loaded track *l* before it reaches the slope track *s*.

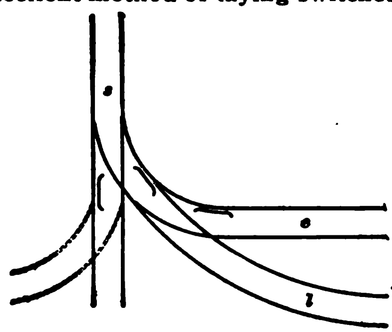


FIG. 18

28. Fig. 19 shows a plan *A* and profile *B* of a switch

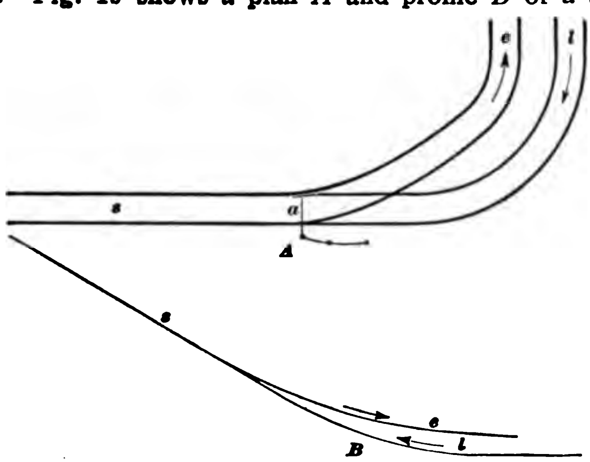


FIG. 19

used at the bottom of a slope. The figure shows one side

only of the slope, the other side being similar. At the switch *a* there is a pair of spring latches set for the empty track *e* and which causes the empty car coming down the slope to take this track. The empty cars pull the rope in to where it can be attached to the loaded cars, which are standing near the slope on the road *l*.

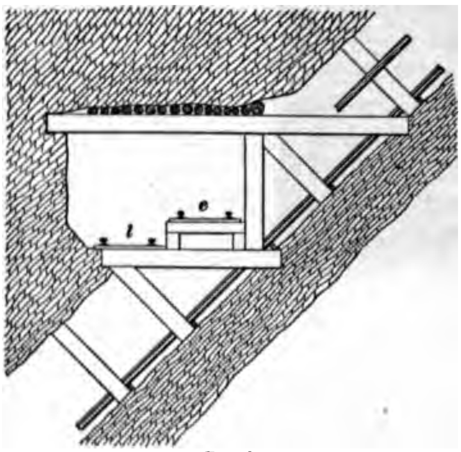


FIG. 20

29. Fig. 20 shows a cross-section of the slope landing shown in Fig. 19 when the empty track *e* is higher than the loaded track *l*, so that both the loaded and empty cars can be handled by gravity.

30. Fig. 21 shows a slope landing at which the loaded

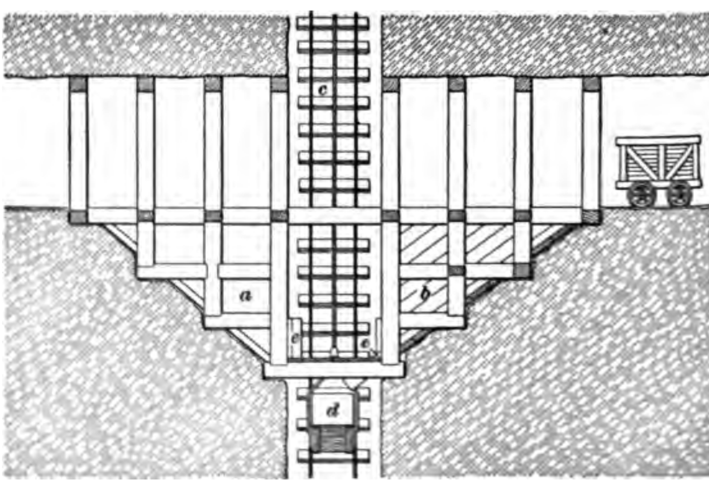


FIG. 21

cars can be dumped into small pockets *a* and *b* on either side

of the slope *c*. As soon as a trip of loaded cars comes in to the pockets, the cars may be dumped by an ordinary cradle dump, not shown, and then returned, thus decreasing the number of cars in use over those that would be required were the cars obliged to wait while the gunboat *d* made a trip. The pockets are supplied with gates and aprons *e* worked by a loader who stands on a platform just above the gunboat. In the illustration, but one gunboat is shown, although two may be used as readily as one, requiring, however, a double-track slope. The great objection to dumping direct into gunboats from levels or loading from chutes is that coal is likely to roll down the slope, but if care is used in dumping and proper swing chutes are employed for directing the coal into the gunboat it can be performed satisfactorily. Pockets are not generally used at slope landings and the mine cars are usually dumped directly into the gunboat, but there are a few mines where an arrangement similar to that shown in Fig. 21 is used.

GRADES OF BOTTOMS AND LANDINGS

31. In all shaft or slope bottoms or landings, the grade of the loaded track should favor the movement of the loaded cars toward the shaft or slope. The empty track starting from the shaft or the foot of the slope should have a descending grade. Considerable work is often necessary to establish the proper grades on these tracks. It is frequently necessary to lift a large amount of bottom or to take down a large amount of top at the foot of the shaft to obtain the proper grade for the loaded cars, but it is very essential that easy grades be established if the cars are to be economically handled at the shaft bottom. Track grades will be considered more in detail in the study of mine haulage, but the loaded track of a shaft bottom or landing should have a grade varying from 1 to 2 per cent., according to the conditions. The grade of the empty track starting from the foot of the shaft may be 2 per cent. for, say, the first 10 yards, reducing to $1\frac{1}{2}$ per cent. for the following 20 yards, and gradually reaching a level at, say, 50 yards from the shaft.

The grade of the loaded track falls toward the shaft or the bottom of the slope, so that the loaded cars run by gravity to the shaft or to the point where the slope rope is hooked on. The empty track is inclined in an opposite direction, so that the empties also run by gravity from the shaft or from the bottom of the slope after being unhooked from the rope.

Instead of thus arranging the grades of the loaded and empty tracks at the shaft or slope bottom, or landing, a short chain car haul is sometimes used to move the loaded cars forwards to the cage or to the foot of the slope. The track may then be level or, if necessary, may even have an up grade to the shaft. The trip of loaded cars is hauled very near to the bottom of the shaft. The cars are uncoupled, one by one, and pushed forwards a few feet where the dogs of the short chain haul grip the axle of the car and move it to the cage, or to the main slope haul.

LOCATION OF STABLES, PUMP ROOMS, ETC.

32. Mine Stables.—In the location of the mine stable, the following points should be considered: the prompt rescue

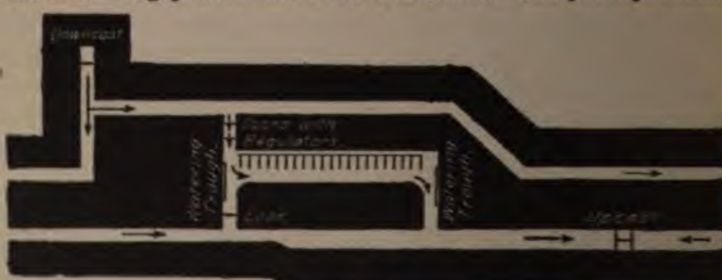


FIG. 22

of the mules in case of accident; the ventilation of the stable by a separate split of fresh air without contaminating the air-current passing into the mine; the handling of the daily stable refuse and feed to and from the surface; water supply; distance from the stable to the working face. The stable is generally located near the bottom of the shaft, especially during the early development of the mine; though sometimes

later and after the workings have become extensive the stable may be moved to some convenient second opening or air-shaft where the mules will be closer to the working face and can still be rescued promptly and fed and cared for economically.

In Figs. 11 and 12, the stables were shown in the shaft pillar, and ventilated by an air split that passes directly from the main intake through the stables to the main return. Fig. 22 shows a mine stable located in the entry pillar at the shaft bottom, the pillar being widened out for this purpose. In all these arrangements, no door is required at the entrance of the stable, but regulators are placed at the rear end of the stable to control the supply of air entering the stable from the main intake.

The question of water supply for the stables is sometimes a troublesome one. Where the mules cannot drink the mine water, as is usually the case, a supply of water must be piped to the stable from the surface. It is important to maintain a bar or chain at the entrance of the stable, to prevent mules that get loose from wandering into other parts of the mine; the instinct of the mule will almost invariably lead him to the sump where he may be drowned.

33. Pump Room.—The pump room frequently is located near the foot of the pump way of the main hoisting shaft, as shown in Fig. 23. The use of a compartment of the hoisting shaft for pumping, however, often proves a serious inconvenience in the operation of the mine, owing to the exhaust steam filling the shaft and shaft bottom so as to interfere with the work of hoisting. With the pump room located in the shaft pillar between the downcast or air-shaft and the main hoisting shaft, as shown in Fig. 23, this trouble is avoided.

It frequently happens that owing to the varying grades in the seam it is impracticable to drain all the mine workings to a sump at the shaft bottom. In such cases, a sump is often located at some convenient low point in the workings, and the pump room is then located at this point, and the water

pumped to the surface through bore holes drilled for this purpose. The steam supplying the pump is likewise conducted in pipes from the boilers at the surface to the pump in the mine through a bore hole.

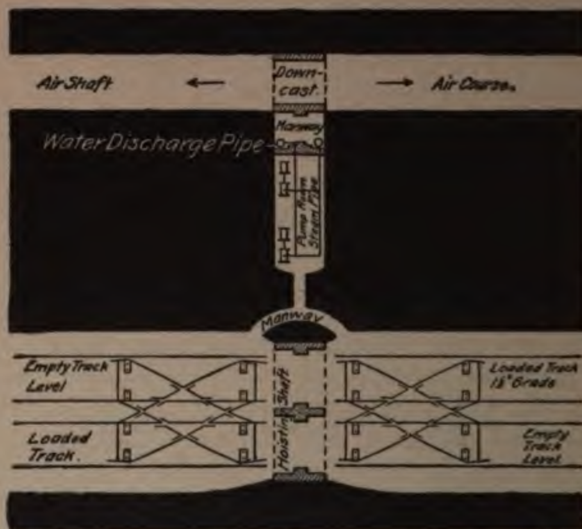


FIG. 23

34. Engine Room.—The engine for rope haulage is often located at some point in the mine, and where steam is used for power it may be taken down the shaft and along the entry to the engine room, or down a bore hole that opens into the mine near the engine room. The engine may exhaust into a pipe leading up the shaft, or bore holes for this purpose may be sunk from the surface at the point where the engine is located. The engine room is an opening made in the shaft pillar or, if away from the shaft, in the entry pillar, which is then made larger to provide for the room. The roof over the engine room is well secured by solid timbers, or by steel I beams supported on brick or concrete walls at the sides of the room. The engine should be placed so that the pull of the rope will be as direct as possible.

35. Lamp Stations.—In a very gaseous mine where none but safety lamps are used in the workings, the lamp room or lamp station is generally located at the surface. In many gaseous mines, however, safety lamps are restricted to a portion of the workings only and naked lights are used in the other portions of the mine. In such cases, lamp stations are frequently provided at some point on the main intake of the mine near the mouth of the entries or headings leading to these workings. Similar lamp stations, called *relighting stations*, are likewise often provided at different points on the main intake wherever safety lamps are used, where lights that have been extinguished may be relighted. A lamp station is a simple opening made in rib or pillar coal on the intake airway, where a strong current of pure air is passing, and where safety lamps may be kept or relighted when extinguished.

36. Shanties.—The various other shanties used in the operation of the mine, such as the mine-boss shanty, tool shanty, oil house, etc., as well as the wash rooms and hospital rooms, are simple openings made in the shaft or entry pillar, the size and arrangement depending on its use. Many mines now have wash rooms and hospital rooms at the shaft bottom, supplied with steam and water pipes, for the convenience of the men and for the care of the injured. The walls of these rooms, as also those of the mine-boss shanty, are often cemented and whitewashed, and the floors are also cemented so that they can be kept clean and comfortable. Tool shanties are often located at convenient points for the distribution of the tools to the company men, and sometimes there are blacksmith shops in the mine for the sharpening of the tools, though this is generally done at the surface.

37. Manway About the Shaft.—A small manway should encircle at least one end of every hoisting shaft. This manway is sometimes made by enlarging the shaft excavation by widening on the rib, as shown in Fig. 14, but this is not a good plan. At other times, a narrow heading or passageway is driven in the solid coal from one side of the

shaft to the other, as shown in Fig. 15. This manway in the shaft pillar is objected to by some as endangering the shaft pillar, but allowance can be made for it in laying out the size of the shaft pillar, and it can be well timbered, if necessary, so as to run no risk of weakening the strata near the shaft. No hoisting shaft should be operated without such a manway, in order to avoid the risk to which the cager is exposed if obliged to pass under the moving cages.

MASONRY AND STEEL CONSTRUCTION UNDERGROUND

38. For permanent work underground, such as the walls of shaft bottoms, turnouts, pump houses, engine rooms, etc., it is now common practice to use a very substantial construction of masonry or of masonry and steel combined.

The use of concrete for building drift mouths and for lining shafts was described in *Drifts, Slopes, and Shafts*, and the composition of the concrete mixture for work of this character can be found there. The first cost of masonry linings and supports is greater than that of timber, but if properly constructed they are permanent and require little or no repair, whereas timber must be constantly renewed.

FIG. 24

39. Masonry and Wood or Steel Supports. Where the walls are not subjected to heavy side pressure and where the passageway is narrow, but requires some support, straight brick, or concrete walls can be used as shown in Fig. 24 with wooden or steel beams and lagging above them. Wooden beams can be used to advantage if the mine water is acid,

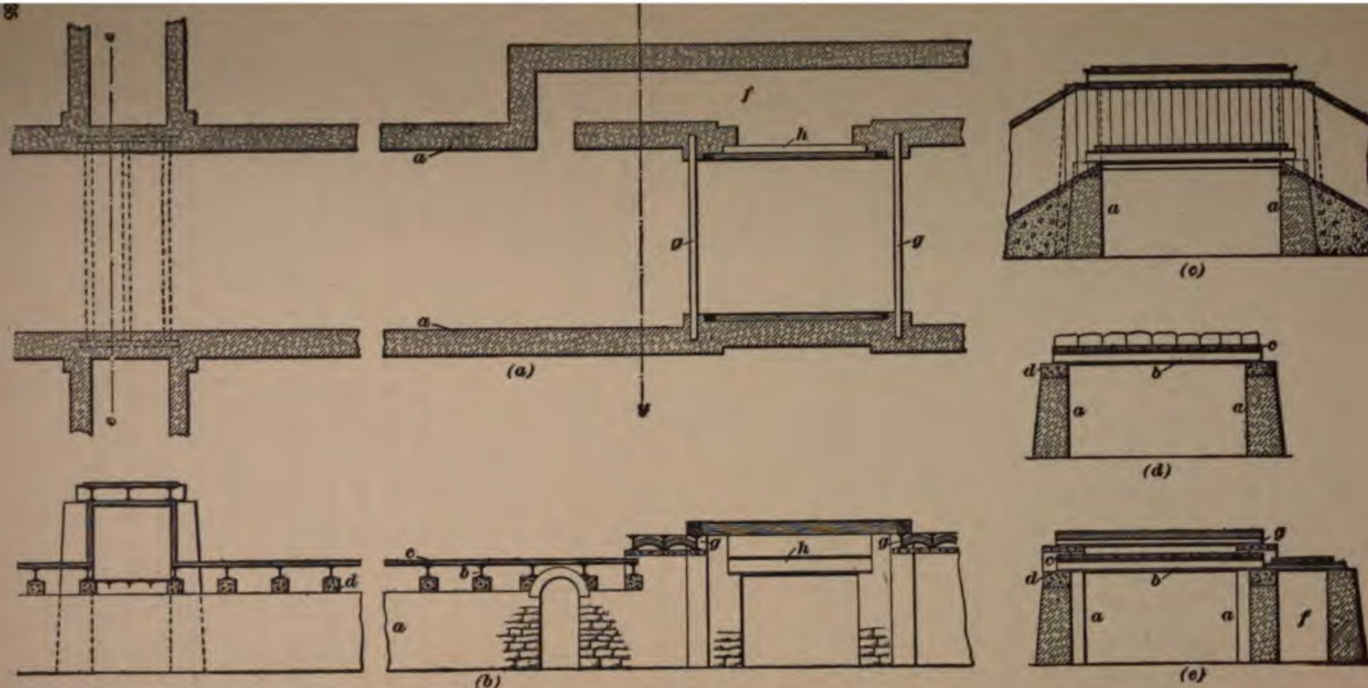


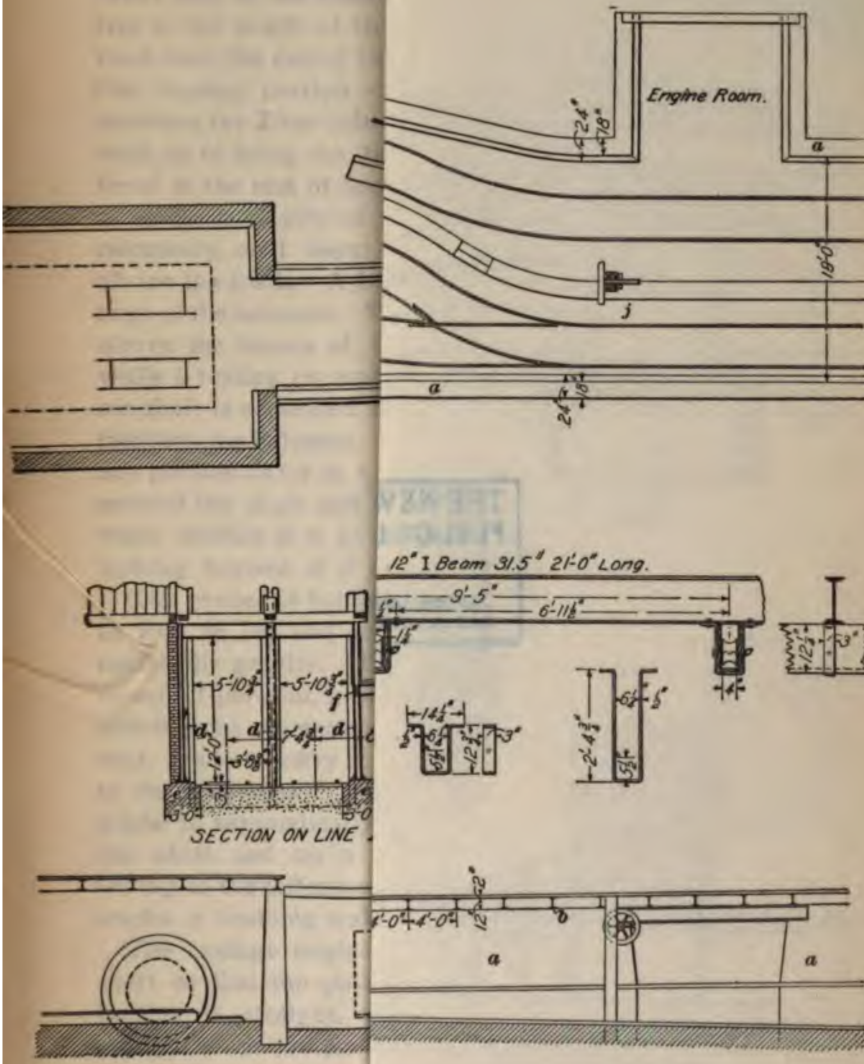
FIG. 25

rtain conditions metal beams may be destroyed wooden beams.

. 25 shows a double-track shaft bottom in which e supported by stone walls *a* and the roof by above which 3-inch plank lagging *c* is placed. e 1 eams are used in this way, it is sometimes o rest the ends of the beams on timber laid as ng the top of the wall, in order to distribute the more evenly over the wall and to give a better bear- he steel be ction to this method is that imber is apt to g the beams to settle. A arrangement is that in Fig. 25 where a small foundation plate *d* is laid for the ends of each beam. 25, (*a*) is a general plan; (*b*) is an elevation of the ft bottom; (*c*) is a section through the overcast on the ; (*d*) is a section of the main haulage way; (*e*) is a n near the shaft on a line *yy* showing the manway *f* the I beams *g* that support the shaft linings. The top above the manway is supported by old T-iron rails. Old rails can frequently be used to advantage in this way for short spans and they give a strong and cheap support.

41. Steel and Masonry Shaft Bottoms.—The arrangement of the shaft bottom at the Mammoth Mine of the H. C. Frick Coke Company is shown in Fig. 26. The bottom, on both sides of the shaft, is enclosed by stone walls *a*. These walls carry 12-inch I beams *b*, *b'* that support the roof. On account of the air compartment at one end of the shaft, the empty track is brought in close to the cageways to avoid unnecessary cutting of material around the shaft. The shaft timbering is supported on I beams *c*, *c'* that, in turn, are supported by means of steel Z-bar columns *d* resting on stone foundation walls *e*. The I beam *c'* on top of the posts on the front side of the shaft is 12 feet above the top of the rail, thus giving sufficient headroom so that 30-foot rails can be brought into the mine.

The roof on this side is sloped down so that the height between the top of the loaded track and the bottoms of the


Engine Room.
12" I Beam 31.5# 21'-0" Long.
9'-5"
SECTION ON LINE

I beams *b* supporting the horizontal roof is 7 feet, the Z-bar columns *d'*, *d''* supporting the sloping roof on the side of the shaft next to the empty track being reduced in length according to the height of the roof. The I beams *b'* supporting the roof over the empty track opposite the end of the shaft and the sloping portion of the roof are riveted to I beams *f*, between the Z-bar columns, the height of the roof being made such as to bring the bottom of the I beams *b'* on the same level as the rest of the beams *b* of the roof.

At the back side of the shaft where great headroom is not necessary, an I beam *g* is placed between the posts 7 feet above the track. A brick wall was built on this beam to the tops of the columns. The spaces between the columns *d*, *d'*, *d''* above the beams of the empty track are closed by brick walls *h* resting on steel plates on top of the I beam *f*. The air-shaft is separated from the cageway by a brick wall built between the columns. The loaded track and the empty track are parallel as far as a point *j*. Here the empty track passes around the shaft and on to the back switch *k*. The loaded track divides at *m* to carry cars to either cage, the tracks uniting beyond at *k* continue to the kick-back.

The grades of both the loaded and empty tracks are shown in Fig. 26 (*b*) and are such that the cars can be handled mainly by gravity. The loaded cars from the knuckle run down a 1-per-cent. grade to the cage, bumping off the empty, which gains momentum enough in passing down a 4.893-per-cent. grade to carry it up an ascending grade of 15 per cent. to the kick-back. The empty car on returning down the grade is automatically switched to the empty track around the shaft and up a 1.98-per-cent. grade to the knuckle. Owing to the difference in elevation of the loaded and empty tracks, a retaining wall is necessary between the two.

The haulage engine room is located directly back of the shaft so that the pull from the engines to the end of the landing is straight, the rope passing between the inner guides of the two hoisting compartments. The entrance to the engine room is through a brick-arch opening from the side wall of the shaft bottom.

42. An ingenious method of walling an entry where the sides are weak but the roof good is shown in Fig. 27. On each side of the road, at intervals, brick walls *a* are built and between them walls *b* of slate or rock bound together by cement mortar consisting of four parts sand and one part

FIG. 27

cement. Along the top of the walls so constructed, a wooden stringer *c* is placed. If the roof is good, no lagging is used; but in every case the metal **I** beams *d* are tightly wedged against the roof above the wall.

43. Another method of supporting the walls and roof where the latter is comparatively good, consists in building rough walls *a* at stated distances along the sides of the road, Fig. 28. These walls are carried to within a few inches of

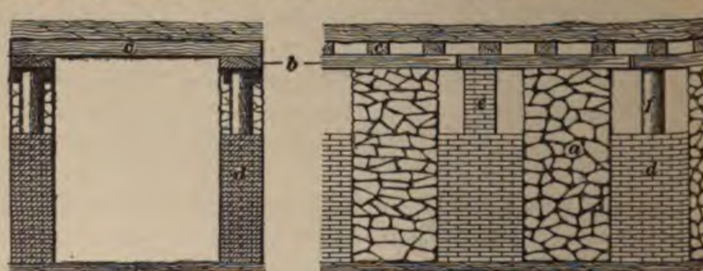


FIG. 28

the roof where a space is left for the sill *b* and the cross-beams *c*. Between these, walls of brick *d* are built up to about two-thirds the height of the road, and on top of these short pillars of brick *e* or short wooden props *f* are placed to support the stringers. This wall is said to act better than a solid brick wall as it deflects to a considerable extent

before giving way. Further, it is cheaper than solid brick masonry both for material and for the labor required.

44. Another system, Fig. 29, is employed where the roof is good, but where slabs of coal are liable to fall from the ribs into the roadway, the lower part *a* is a continuous wall of concrete. On this wall, at regular intervals, brick pillars *b* are erected and between them short props *e* are placed to support the stringers *d*. This walling and timbering gives

FIG. 29

general satisfaction, is easy to repair, and when properly constructed will last as long as that part of the mine in which it is placed.

45. The methods illustrated in Figs. 27, 28, and 29 are in use in England where these forms of support are employed not only about the shaft bottom, but also sometimes along permanent roads.

Permanent supports of the kind illustrated in Figs. 24 to 29 inclusive are not generally used in American mines except about the shaft bottom and for a few hundred feet along the entries radiating from the shaft bottom, since it is generally possible to secure the top and sides of the mine passageways with timber, which costs less.

46. Advantages of Masonry and Steel Construction.—The advantages claimed for brick or stone walls with steel girders instead of brick or concrete arches alone are as follows: Less space is required to be excavated for a given area, as the roof is flat instead of arched, the saving in this respect being nearly 25 per cent. Less labor and

TABLE I

[illegible]S OF STANDARD I BEAMS

[illegible]pth of [illegible]eam [illegible]nches	Weight per Foot Pounds	Area of Section Square Inches	Thickness of Web Inches	Width of Flange Inches	Moment of Inertia, Neutral Axis Perpendicular to Web at Corner I	Section Mod[illegible] Neutral A[illegible] Perpendicu[illegible] to Web at Ce[illegible] S
24	100.00	29.41	.754	7.254	2380.3	198.4
	95.00	27.94	.692	7.192	2309.6	192.5
	90.00	26.47	.631	7.131	2239.1	186.6
	85.00	25.00	.570	7.070	2168.6	180.7
	80.00	23.32	.500	7.000	2087.9	174.0
20	75.00	22.06	.649	6.399	1268.9	126.9
	70.00	20.59	.575	6.325	1219.9	122.0
	65.00	19.08	.500	6.250	1169.6	117.0
18	70.00	20.59	.715	[illegible]	921.3	102.4
	65.00	19.12	.637	[illegible]	881.5	97.9
	60.00	17.65	.555	[illegible]	841.8	93.5
	55.00	15.93	.460	[illegible]	795.6	88.4
15	55.00	16.18	.656	5.746	511.0	68.1
	50.00	14.71	.558	5.648	483.4	64.5
	45.00	13.24	.460	5.550	455.8	60.8
	42.00	12.48	.410	5.500	441.7	58.9
12	35.00	10.29	.436	5.086	228.3	38.0
	31.50	9.26	.350	5.000	215.8	36.0
10	40.00	11.76	.749	5.099	158.7	31.7
	35.00	10.29	.602	4.952	146.4	29.3
	30.00	8.82	.455	4.805	134.2	26.8
	25.00	7.37	.310	4.660	122.1	24.4
9	35.00	10.29	.732	4.772	111.8	24.8
	30.00	8.82	.569	4.609	101.9	22.6
	25.00	7.35	.406	4.446	91.9	20.4
	21.00	6.31	.290	4.330	84.9	18.9
8	25.50	7.50	.541	4.271	68.4	17.1
	23.00	6.76	.449	4.179	64.5	16.1
	20.50	6.03	.357	4.087	60.6	15.1
	18.00	5.33	.270	4.000	56.9	14.2
7	20.00	5.88	.458	3.868	42.2	12.1
	17.50	5.15	.353	3.763	39.2	11.2
	15.00	4.42	.250	3.660	36.2	10.4
6	17.25	5.07	.475	3.575	26.2	8.7
	14.75	4.34	.352	3.452	24.0	8.0
	12.25	3.61	.230	3.330	21.8	7.3
5	14.75	4.34	.504	3.294	15.2	6.1
	12.25	3.60	.357	3.147	13.6	5.4
	9.75	2.87	.210	3.000	12.1	4.8
4	10.50	3.09	.410	2.880	7.1	3.[illegible]
	9.50	2.79	.337	2.807	6.7	3.[illegible]
	8.50	2.50	.263	2.733	6.4	3[illegible]
	7.50	2.21	.190	2.660	6.0	3[illegible]
3	7.50	2.21	.361	2.521	2.9	[illegible]
	6.50	1.91	.263	2.423	2.7	[illegible]
	5.50	1.63	.170	2.330	2.5	[illegible]

time are required for erection, and therefore the cost is reduced.

In soft strata, girders can be placed as the work proceeds, where with brick arching temporary center supports must be used, thus increasing the cost and blocking up the passageway.

Girders can easily be removed from one part of a mine to another and be used over again, whereas brick or concrete work can seldom be removed and is lost when that part of the mine in which it is erected is abandoned.

The advantage of steel beams over timber is that they are lighter and easier to handle than wooden beams having the same strength. There is no risk of their catching fire. They do not decay. They give increased space for air to circulate on account of their size for a given strength being less than timbers.

47. The cost of I beams varies greatly at different times and depends on the location of the mine, which determines the freight rates. The average price of structural beams is about 1.7 cent per pound, although at times it goes as low as $28 per ton. Steel beams are about twice as expensive as timber, but on the other hand they will last from four to six times as long where the conditions are favorable to their use. Owing to varying conditions in different mines, the size of girders must be regulated to the weight that comes on them. Girders should have a web at least 5 inches high in order to have stiffness, and the weight per pound per lineal foot should increase as the span increases.

48. Table I gives the Carnegie standard sizes of I beams. There are two sizes for each depth, in inches, of the beams, due to the increased quantity of metal placed in them by different thicknesses of web.

49. **Rail Beams.**—In some instances, old rails are used as beams when they can be obtained cheaply from the railroads. A method of using them on wooden posts is shown in Fig. 30. To prevent the legs being pushed in at the top, an iron band *a*, as shown in Fig. 30 (*b*), is placed about the

rail *b* and in front of the post at *d*. Wedges *c* are then

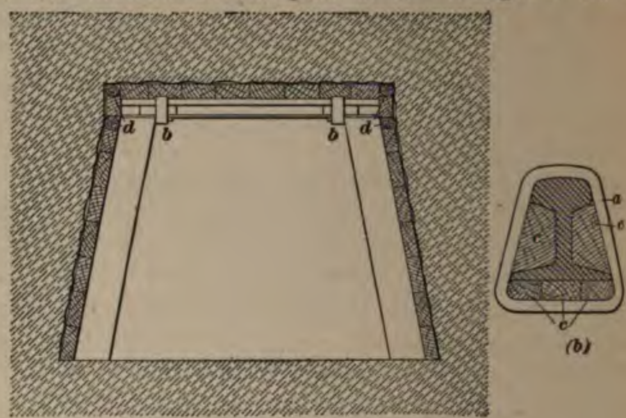


FIG. 30

driven in tightly to prevent the band from slipping and the ends of the rails are firmly wedged above the post.

IRON OR STEEL PROPS AND SETS

50. Iron or Steel Props.—Fig. 31 is a hollow iron prop made in two sections with a sleeve *a*. This prop has been used in long-wall working where it is necessary to draw the prop to let the roof sag. By knocking up the sleeve, the prop falls and can be pulled out of danger. In case one or the other section of the prop is buried by rock, it can usually be recovered by the chain attached, which is sufficiently strong for recovering the end from under the first fall. There is considerable danger of the cast-iron sleeve *a* splitting when pressure comes on the prop.

FIG. 31

Fig. 32 (*a*) shows the section of an **I** beam that has its web *a* cut down so that the flanges *b* can be turned down over it, as shown in Fig. 32 (*b*), to form a prop. As these props are more expensive than wooden props, there are holes *c* punched in the web for the insertion of a hook to help withdraw them so that they may be used over and over again. Cast-iron props are

heavy and are liable to become broken when drawn; these being lighter and also tougher are preferred. The I prop is patented and is known in England as the *Firth prop.*

51. Iron or Steel Sets.—Iron or steel beams are best adapted to haulage roads where the pressures are fairly uniform and the strata have settled. Steel girders seldom break when subjected to sudden pressure, but they bend in the center, and these deflections may be sufficient to make the area of the haulage road too small; therefore, the strata should have settled or the pressures be uniform where iron sets are used, otherwise the legs of the frames or sets should be set down, leaving the road bed high, as in Fig. 33, so that when settling occurs the track bed may be lowered. Settling of strata is not as likely to occur in roadways where

FIG. 32


FIG. 33

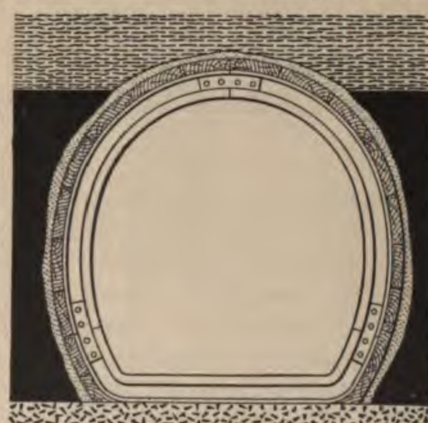


FIG. 34

pillar-and-room work is carried on as in other methods of working coal deposits.

Iron and steel I-beam sections weighing from 24 to 60 pounds per yard are sometimes bent in the form of a

horseshoe as in Fig. 34; and where two such sections meet they are joined by fishplates, bolts, and nuts.

When roof and sides are both soft and the floor is given to creeping, the metal sections are worked to form as shown in Fig. 34, joined by fishplates, and then lagged with wood. The sets are placed about 2 feet apart and the lagging driven in as tight as possible. In place of fishplates, wrought-iron bands may be slipped over the joints and held in place by wooden wedges.

52. Cast-iron posts with I-beam caps have been employed in a Staffordshire Colliery in England. The posts were made hollow and flanged at the ends as in Fig. 35 (*a*).

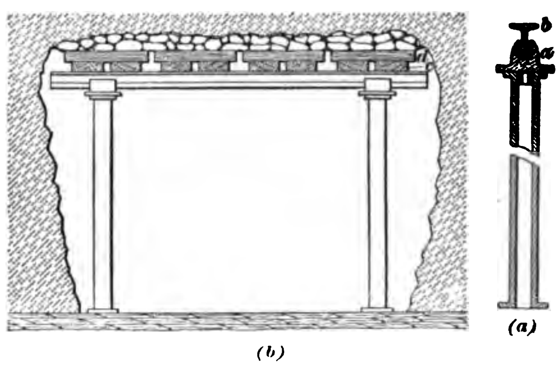


Fig. 35

A cast-iron chair *a* was made to fit into the post and receive the cap *b*. In the illustration, the chair was made for a 50-pound rail, which was reversed so that the head of the rail would slip into the horns of the chair as shown and the bottom of the rail be upwards. The lagging *c*, Fig. 35 (*b*), was of wood and above this were placed planks *d* forming a double lagging filled in above with waste to make a tight joint with the roof rock. The planks *d* placed on the lagging *c* saved timber.

53. Fig. 36 shows an example of the use of steel sets in the anthracite mines of Pennsylvania. There are two methods used in these mines for connecting the legs and collars of these steel sets. Fig. 37 shows a detail of the

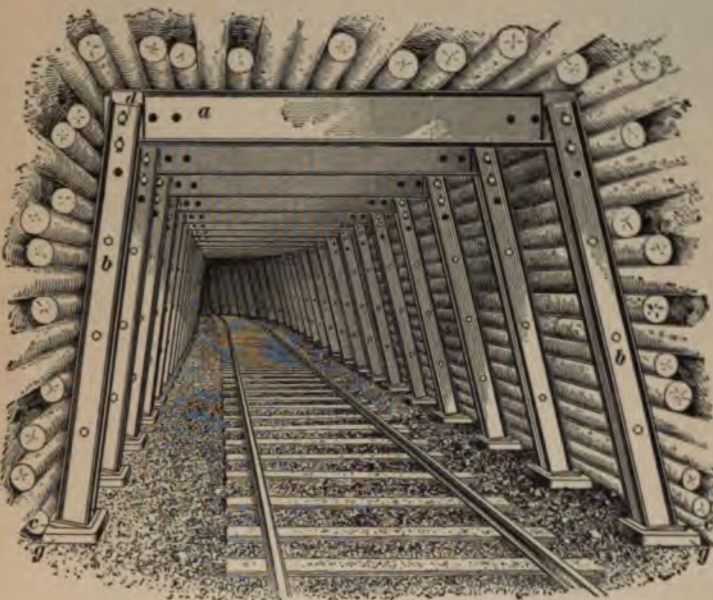


FIG. 36

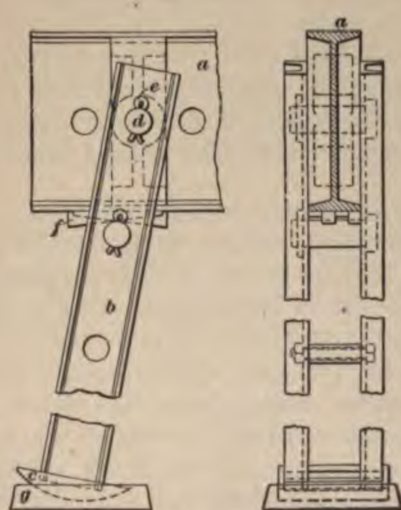


FIG. 37

pin-connected type; the cap piece *a* is an I beam, while each leg *b* consists of two channel beams that rest in a cast base *c* at the bottom. The top of each leg is fastened to the cap by means of the pin *d*, held in place by the split cotters *e*. Iron wedges *f* are also used to stiffen the connection between the cap and the leg. Several pinholes are made in both the legs and the collars, so that the same set may thus be used in several positions. In order that the legs may be given a desired batter, the legs of the posts fit into a cast shoe *c* that has a cylindrical bottom, and this bottom rests in a cast base *g*. This forms a very easily adjustable set, for by means of the base illustrated the legs can be given any desired batter, and the set is then stiffened by means of the wedges *f*.

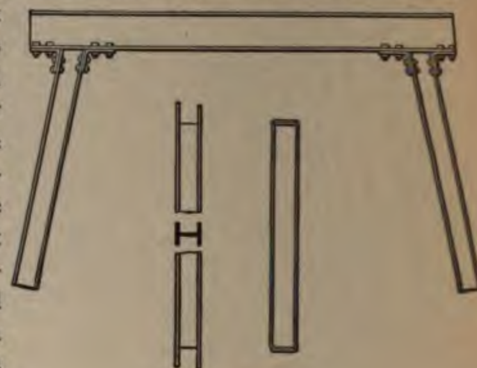


FIG. 38

Another form of metal set is shown in Fig. 38 and while cheaper then the one shown in Fig. 37 it is not as flexible. It consists of I beams both for the cap and legs, held together by means of angle irons riveted to the I beams as shown.

CONCRETE SHAFT BOTTOM

54. Fig. 39 shows the arrangement of the shaft-bottom of the River Coal Company at Brownsville, Pennsylvania, where concrete is used for the shaft lining and shaft bottom support. The coal is reached by three openings, the slope *a*, which is used as a manway and for taking timber and supplies into the mine, the main hoisting shaft *b*, and the air-shaft *c*. The main entry *d* has two tracks, which are used for loaded cars and for switching the locomotives. The empty cars are bumped from the cage by the loaded cars and run down an incline *e*, Figs. 39 and 40, and the kick-back *f*,

from which, by means of suitable switches, the empty cars pass through the cross-entry *g* into the entry *h* where the trips of empty cars are made up and taken into the side

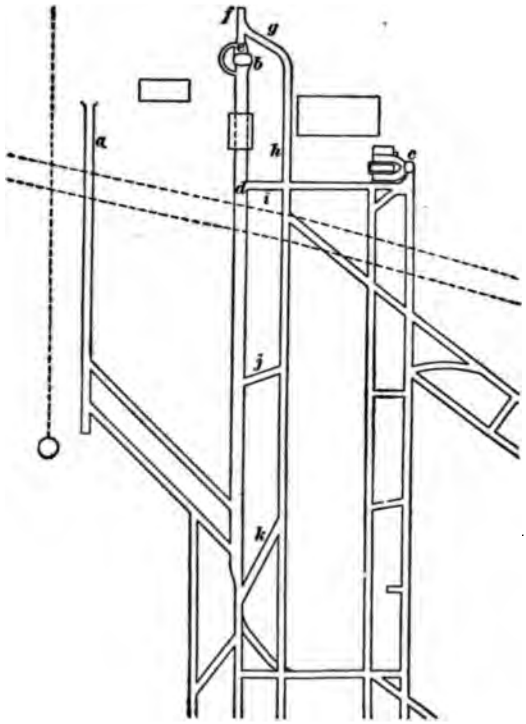


FIG. 39

entries. Cross-cuts *i* and *j* between the loaded and empty entries are for ventilation purposes only; and are not connected for haulage purposes until the cross-over *k* is reached. The connection of the shaft lining *l* with the entry lining *m* is shown in Fig. 40, and in Fig. 41 (*b*) and (*c*). Shafts *b* and *c* are lined with concrete and have curved sides and ends, as shown in Fig. 41 (*a*). Buntons *u*, *o*, *p* dividing the shaft into compartments are steel beams, shown in detail in Fig. 41 (*d*) and (*e*). The cage guides *q*, Fig. 41 (*a*), (*d*), and (*e*), are bolted to blocks *r*, which in turn are bolted to the I beams shown in (*d*) or the] beams shown in (*e*).

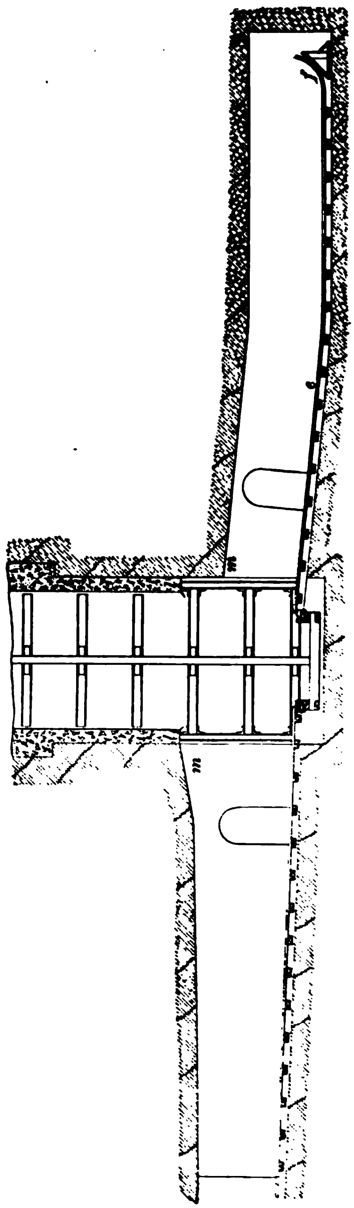
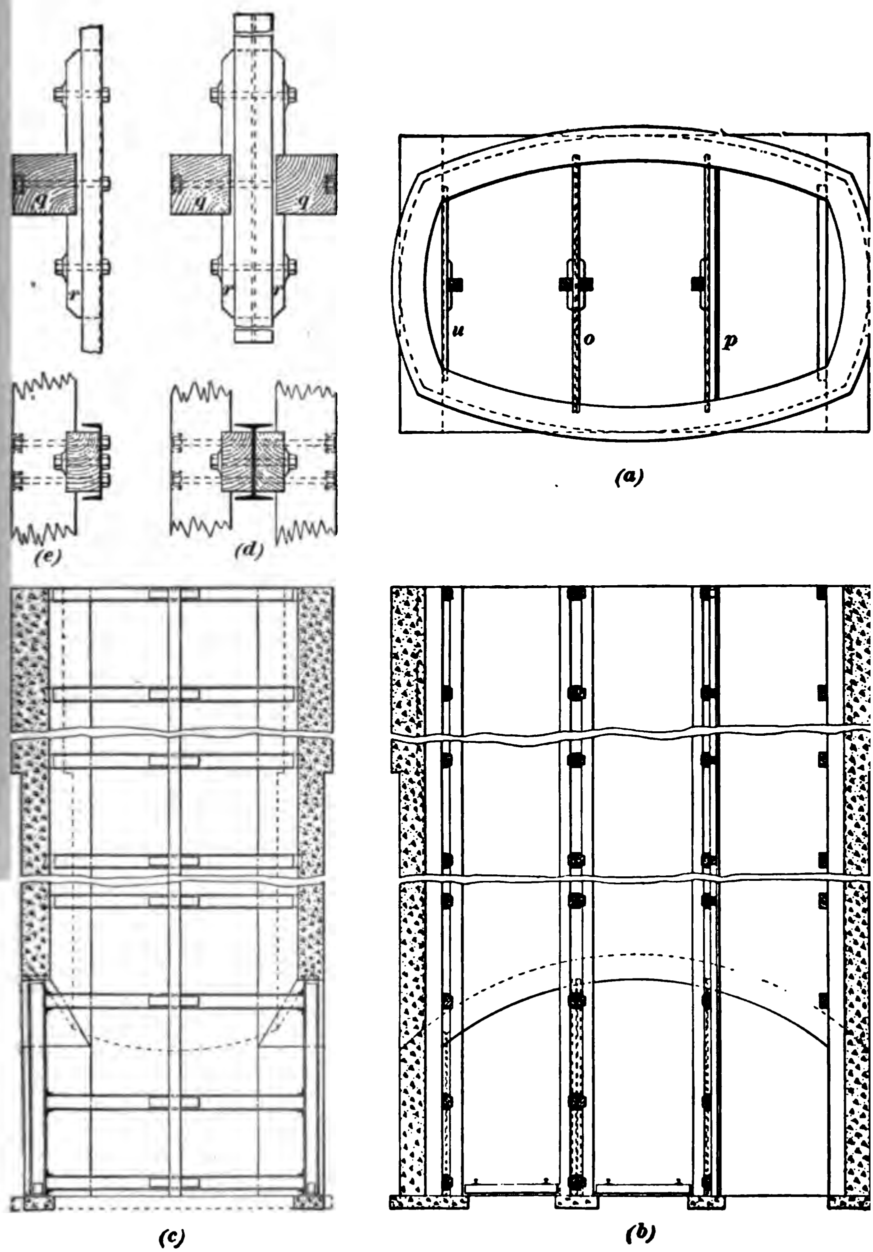


Fig. 40



49 FIG. 41